UNIVERSITY OF PENNSYLVANIA

CONSTRUCTION OF A DIAGNOSTIC TEST IN THE MECHANICS AND RELATED FUNDAMENTALS OF HIGH SCHOOL CHEMISTRY

JOSEPH E. MALIN

A THESIS
IN EDUCATION
PRESENTED TO THE FACULTY OF THE GRADUATE SCHOOL IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

PHILADELPHIA
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CONTENTS

CONSTRUCTION OF A DIAGNOSTIC TEST IN THE MECHANICS AND RELATED FUNDAMENTALS OF HIGH SCHOOL CHEMISTRY

PAGE

I. The Problem and the Procedure. 9
1. Definition of the Problem
2. A Survey of the Field
3. The Plan of Procedure

II. Establishing the Validity of the Tests. 25
1. Textbook Analysis and the Selecting of Items
2. College Entrance Board Examination Analysis
3. Standard Minimum High School Course in Chemistry as Proposed by the American Chemical Society
4. Questionnaire Analysis

III. The Data and Their Significance for Forms A and B..... 70
1. The Administration of the Tests
2. The Distribution of Scores
3. The Per Cents of Correct Responses to Each Question
4. The Analysis of Part I in Forms A and B
5. The Analysis of the Types of Error in Part I for Forms A and B
6. The Analysis of the Types of Error in Part II for Forms A and B
7. An Analysis of Combinations of Errors
8. Conclusions

IV. A Comparison of the Results of Forms X and Y with Those of Forms A and B..... 149
1. The Construction of Form X
2. A Comparison of the Per Cents of Correct Responses
3. A Comparison of the Types of Error
4. The Construction and Use of Form Y
5. Conclusions

V. Value and Uses of the Diagnostic Tests. 168
1. For Diagnosing Pupils' Difficulties in the Mechanics of High School Chemistry and Its Related Fundamentals
2. For Proposing Remedial Measures
3. For Checking the Results of Remedial Measures
4. For the Improvement of the Teaching Method

VI. Conclusions. 192
1. Validity
2. Diagnostic Results
3. Results of Revisions in Forms A and B
4. Uses of the Tests

CONTENTS - *Continued*

PAGE

APPENDIX

Tables LXVII-LXXXVIII. 198
Correlations. 226
Directions for Administration of the Tests. 227
Copies of the Various Forms of the Diagnostic Tests:
1. Part I of Preliminary Form A. 230
2. Form A (Unrevised). 231
3. Form A. 238
4. Form B. 243
5. Form X. 248
6. Form Y. 250
Copy of the Questionnaire. 251
Bibliography. 254
List of Available Chemistry Tests. 259
Basic and Supplementary Texts and Manuals Used in 101 School Systems of the United States. 259

TABLES

I. Total Number and Per Cent of Types of Problem Occurring in the Five Selected Textbooks. 32
II. Total Number and Per Cent of Sub-types of Equation Problem Occurring in the Five Selected Textbooks.. 32
III. Total Number and Per Cent of Pages Devoted to Gaseous Elements and Compounds in the Five Selected Textbooks. 35
IV. Total Number and Per Cent of Pages Devoted to Gaseous Elements and Compounds in the Six Selected Textbooks. 36
V. Total Number and Per Cent of Pages Devoted to Gaseous Elements and Compounds in the Five Selected Manuals. 37
VI. Total Number and Per Cent of Pages Devoted to Subtopics in Gases in the Six Selected Textbooks..... 37
VII. Total Number and Per Cent of Pages Devoted to Laws and Theories in the Six Selected Textbooks..... 38
VIII. Total Number and Per Cent of Pages Devoted to Different Types of Equation in the Six Selected Textbooks 38
IX. Total Number and Per Cent of Pages Devoted to Problems in the Six Selected Textbooks. 39
X. Total Number and Per Cent of Pages Devoted to the Sub-types of Problem in the Six Selected Textbooks. 40-42
XI. The Ranking of the Gases from the Analysis of Six Selected Textbooks, Five Selected Manuals, and College Entrance Board Examinations. 43
XII. Frequency of Occurrence of the Properties of the Gases in the Six Selected Textbooks. 44
XIII. Frequency of Occurrence of the Properties of Gases in the Five Selected Manuals. 46

TABLES - *Continued*

		PAGE
XIV.	Frequency of Occurrence and Rank of Properties in the Six Selected Textbooks and Five Selected Manuals.	46
XV.	The Ranking of Laws and Theories from the Analysis of Six Selected Textbooks and College Entrance Board Examinations.	48
XVI.	The Ranking of Equations from the Analysis of College Entrance Board Examinations and Six Selected Textbooks.	48
XVII.	The Ranking of Problems from the College Entrance Board Examinations and the Analysis of the Six Selected Textbooks.	50
XVIII.	Frequency Distribution of Topics in Chemistry in College Entrance Board Examinations from 1917 to 1927.	51
XIX.	Frequency Distribution of Sub-topics on Experiments in College Entrance Board Examinations.	51
XX.	The Ranking of Sub-types of Problem from the Analysis of College Entrance Board Examinations and Six Selected Textbooks.	53-54
XXI.	Frequency Distribution of Basic and Supplementary Texts and Manuals Used in 101 School Systems in the United States.	58-61
XXII.	Frequency Distribution of Chemistry Topics Taught in 96 City School Systems in 47 States of the Union.	63-64
XXIII.	Frequency Distribution of Chemistry Topics Taught in 19 Schools in Eastern Pennsylvania and New Jersey.	66-67
XXIV.	Frequency Distribution of Official Positions of the Signers of the Questionnaire.	67
XXV.	Number and Per Cent of Pupils Answering Each Item Correctly in Part II of the Preliminary Test.	71
XXVI.	Total Distribution of Scores in Forms A and B.	81-82
XXVII.	Total Number and Per Cent of Pupils Answering Each Question Correctly in Part I of Form A.	83
XXVIII.	Total Number and Per Cent of Pupils Answering Each Question Correcttly in Part II of Form A.	86
XXIX.	Total Number and Per Cent of Pupils Answering Each Question Correctly in Part I of Form B.	90
XXX.	Total Number and Per Cent of Pupils Answering Each Question Correctly in Part II of Form B.	91
XXXI.	Summary of Tables XXVII and XXIX.	95
XXXII.	Condensed Table for Part II of Form A.	95
XXXIII.	Condensed Table for Part II of Form B.	96
XXXIV.	Percentage Distribution of Horizontal and Vertical Scores in Part I of Form A for the 3-6 Month Period.	99
XXXV.	Percentage Distribution of Horizontal and Vertical Scores in Part I of Form A for the 8-10 Month Period.	100
XXXVI.	Percentage Distribution of Horizontal and Vertical Scores in Part II of Form A for the 3-10 Month Period.	101
XXXVII.	Percentage Distribution of Horizontal and Vertical Scores in Part I of Form B for the 3-6 Month Period.	102
XXXVIII.	Percentage Distribution of Horizontal and Vertical Scores in Part I of Form B for the 8-10 Month Period.	103

TABLES - *Continued*

		PAGE
XXXIX.	Percentage Distribution of Horizontal and Vertical Scores in Part I of Form B for the 3-10 Month Period.	104
XL.	Types of Error in Part I of Form A for the 3-6 Month Period.	108
XLI.	Types of Error in Part I of Form A for the 8-10 Month Period.	108
XLII.	Types of Error in Part I of Form A for the 3-10 Month Period.	109
XLIII.	Types of Error in Valence in Form A.	112-113
XLIV.	Types of Error in Nomenclature in Form A,	117-118
XLV.	Types of Error in Formulas in Form A.	119-121
XLVI.	Types of Error in Equations in Form A.	124-126
XLVII.	Types of Error in Ions in Form A.	130
XLVIII.	Types of Error in Problems in Form A.	132-133
XLIX.	Types of Error in Laws in Form A.	135
L.	Combinations of Errors in Parts I and II of Form A for the 3-6 Month Period.	138
LI.	Combinations of Errors in Parts I and II of Form A for the 8-10 Month Period.	139
LII.	Combinations of Errors in Parts I and II of Form A for the 3-10 Month Period.	140
LIII.	Combinations of Errors in Parts I and II of Form B for the 3-6 Month Period.	141
LIV.	Combinations of Errors in Parts I and II of Form B for the 8-10 Month Period.	142
LV.	Combinations of Errors in Parts I and II of Form B for the 3-10 Month Period.	143
LVI.	A Comparison of Per Cents of Correct Responses in Form X with Those in Forms A and B.	152
LVII.	Types of Error in Valence in Form X.	154
LVIII.	Types of Error in Nomenclature in Form X.	156
LIX.	Types of Error in Formulas in Form X.	157
LX.	Types of Error in Equations and Laws in Form X.	158
LXI.	Types of Error in Ions in Form X.	159
LXII.	Number and Per Cent of Pupils Answering Each Question Correctly in Form Y.	161
LXIII.	Types of Error in Laws and Theories in Form Y.	161
LXIV.	Types of Error in Problems in Form Y.	162-163
LXV.	Diagnostic Scores of Part II for Form A.	169
LXVI.	Diagnostic Scores of Part I for Form A.	170

APPENDIX

LXVII.	Total Number and Per Cent of Pages Devoted to the Sub-topics in Gases in the Five Selected Textbooks.	198
LXVIII.	Total Number and Per Cent of Pages Devoted to Laws and Theories in the Five Selected Textbooks.	198
LXIX.	Total Number and Per Cent of Pages Devoted to Different Types of Equation in the Five Selected Textbooks.	199

TABLES - *Continued*

PAGE

LXX. Total Number and Per Cent of Pages Devoted to Problems in the Five Selected Textbooks. 199
LXXI. Total Number and Per Cent of Pages Devoted to the Sub-types of Problem in the Five Selected Textbooks. 200-201
LXXII. The Ranking of the Gases from the Analysis of Five Selected Textbooks, Five Selected Manuals, and College Entrance Board Examinations. 202
LXXIII. Frequency of Occurrence of the Properties of Gases in the Five Selected Textbooks. 203
LXXIV. Frequency of Occurrence and Rank of Properties of Gases in the Five Selected Textbooks and Five Selected Manuals. 203
LXXV. The Ranking of Laws and Theories from the Analysis of College Entrance Board Examinations and Five Selected Textbooks. 204
LXXVI. The Ranking of Equations from the Analysis of Five Selected Textbooks and College Entrance Board Examinations. 204
LXXVII. The Ranking of Problems from the Analysis of College Entrance Board Examinations and the Five Selected Textbooks. 205
LXXVIII. The Ranking of Sub-types of Problems from the Analysis of College Entrance Board Examinations and the Five Selected Textbooks. 206-207
LXXIX. Types of Error in Part I of Form B for the 3-6 Month Period. 207
LXXX. Types of Error in Part I of Form B for the 8-10 Month Period. 208
LXXXI. Types of Error in Part I of Form B for the 3-10 Month Period. 208
LXXXII. Types of Error in Valence in Form B. 209-210
LXXXIII. Types of Error in Nomenclature in Form B. 211-212
LXXXIV. Types of Error in Formulas in Form B. 213-216
LXXXV. Types of Error in Equations in Form B. 217-219
LXXXVI. Types of Error in Ions in Form B. 220-221
LXXXVII. Types of Error in Problems in Form B. 222-224
LXXXVIII. Types of Error in Laws in Form B. 225

GRAPHS

PAGE

I. Percentile Distribution of Scores in Forms A and B in the 3-6 Month Period. 76
II. Percentile Distribution of Scores in Forms A and B in the 8-10 Month Period. 77
III. Percentile Distribution of Scores in Forms A and B in the 3-10 Month Period. 78
IV. Percentile Distribution of Scores in Form A for the 3-6 Month and 8-10 Month Periods. 79
V. Percentile Distribution of Scores in Form B for the 3-6 Month and 8-10 Month Periods. 80

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CONSTRUCTION OF A DIAGNOSTIC TEST IN THE MECHANICS AND RELATED FUNDAMENTALS OF HIGH SCHOOL CHEMISTRY

CHAPTER I

THE PROBLEM AND THE PROCEDURE

1. Definition of the Problem

Since the appearance of Thorndike's "Theory of Mental and Social Measurements" in 1904, the techniques of the construction, uses, and interpretation of tests have been developed and perfected. As the measurement movement in education has progressed, the importance of diagnosis and remedial measures in school work has been realized by the research workers in the field. This realization has resulted in the construction and perfection of diagnostic tests in the "tool" subjects in the elementary grades. The use of these tests in the elementary grades has brought about the introduction of diagnostic tests in the secondary school subjects. However, due to the greater complexity of the subject matter in the secondary field, greater difficulty has been experienced in constructing valid and reliable diagnostic tests.

More measuring instruments of this type are badly needed on the secondary education level. This is especially true in such a subject as chemistry, which lends itself more readily to objective measurement than do such subjects as English and history. The tests in the subject of chemistry are principally of the achievement type.

The purpose of this investigation is (1) to determine what fundamentals of a mechanical nature in chemistry are taught in the secondary schools; (2) to determine what fundamentals are directly related to fundamentals of a mechanical nature; (3) to select for each mechanical process and its related fundamental a number of exercises which will vary in difficulty; and (4) to indicate the uses and the limitations of the test. The

writer, in this investigation, is making no attempt to standardize the test. Only sufficient data from the preliminary and final tests have been collected to show that the material selected is valid for diagnosing pupils' difficulties in the mechanics and their directly related fundamentals of secondary school chemistry.

Since the mechanical phase of the fundamentals of chemistry is so limited in scope, practically all the elements present can be used in the test. In the case of fundamentals directly related to the mechanical phase, the field is again very limited, but too large to be included in its entirety in this test. As a result of these two considerations, the investigator limited his field to the following elements: principle of valence: principle of writing formulas; principle of naming formulas: principle of writing equations; principle of solving numerical chemistry problems; laws and theories directly related to the aforementioned principles; and the properties of gases.

An examination of the above principles reveals their mechanical characteristics. Thus, in the writing of formulas, it is essential that the pupils know the valence of the metallic and non-metallic elements or radicals in the formula. They are then required to know how to write the subscripts for each element or radical so as to make the total valences of the two parts of the formula equal. This process is both a mechanical and a fundamental operation. The process is fundamental because it must be used again and again throughout the pupil's course in chemistry. Applications of the principle of nomenclature are also mechanical in nature since each compound studied is named in acccordance with the principle. Furthermore, this principle is fundamental for the reason that compounds are studied throughout the chemistry course. Equations are fundamental for the same reason. The analysis of representative secondary school chemistry texts shows that equations in the various texts range in number from approximately 200 to 400 and that the equations are distributed throughout each textbook. The numerical problems possess mechanical characteristics since they, too, involve the use of mechanical operatiions of mathematical calculation and formula and equation writing. Since each of the authors of the seven representative high school chemistry texts devotes several pages to chemical

arithmetic aside from the space devoted to problems at the close of the majority of the chapters, they believe numerical problems to be part of the fundamentals of chemistry.

When once the elements of the mechanical fundamentals of chemistry have been chosen, the selection of elements directly related to the mechanics of high school chemistry does not become such a difficult task. For example, if the mechanical phase of the text contains numerical problems based upon the laws of Charles and Boyle, the selection of these laws for the related fundamental phase of the test is the logical choice. The inclusion of fundamentals directly related to the mechanics of chemistry is based upon the principle that the pupil should learn a complete concept in its entirety rather than in unrelated portions. For this reason, the tests contain items on the theory of ionization and items upon the application of the theory in the writing of ions and ionic equations.

The relationship of the properties of gases to the mechanics of chemistry is not as apparant as it is in the cases cited in the preceding paragraph. The mechanical phase has been operating in the laboratory where the pupil has acquired certain routine habits in the observation of the properties of gases. These physical and chemical properties he tests again and again in the same manner. It is, therefore, one of the functions of this part of the test to determine to what extent correct concepts have been formed by these more or less mechanical operations in the laboratory. If, in the case of a few gases, the pupil has not had the opportunity to test their properties by means of experiments, he has, with what he has learned in class and with what is given in this part of the test, sufficient data to determine the properties of these few gases. The properties of gases, besides being related to the mechanical phases of the laboratory work, are directly related to specific items in other parts of the test. In the numerical problems, for example, the computation of the weight of a liter of gas is directly related to its physical property, density, which is one of the properties being tested among the gases.

2. A Survey of the Field

During the past decade several standardized chemistry tests have been constructed and published. The great majority of

these tests are of the achievement type, some of which are presumed to possess diagnostic values. The principal chemistry tests which are available at the present time are listed below. A more complete list is placed in the appendix.

1. Gerry, H. L.: "Gerry's Tests of High School Chemistry."
2. Rich, S. G.: "Rich's Chemistry Test."
3. Powers, S. R.: "Powers' General Chemistry Test."
4. Rauth, J. W., and Foran, T. G.: "Rauth-Foran Chemistry Test."
5. Glenn, E. R., and Welton, L. E.: "Glenn-Welton Instructional Tests in Chemistry."
6. Persing, K. M.: "Persing Laboratory Chemistry Test."
7. Jette, E. R., Powers, S. R., and Wood, B. D.: "Columbia Research Bureau Chemistry Test."
8. Stoddard, G. D., and Cornog, J.: "Chemistry Aptitude Test."
9. .....: "Chemistry Training Test."

The Gerry chemistry tests were developed during the years 1920 to 1922. In the selection of items for this test, Gerry[1] based his choice of materials upon the analysis of College Board questions from 1911 to 1920. Those items of highest frequency which lent themselves to objective statement were chosen for the preliminary tests. This choice of items was checked by reference to four representative chemistry texts, two of which were high school texts and two of which were college texts.

The method of selection of items of apparently the same difficulty from the preliminary tests is quite unique. For example, when two or more questions were answered correctly by the same number of pupils, Gerry chose that item which showed the highest per cent of pupils answering all the easier questions correctly. To illustrate, suppose two items are answered correctly by 60 per cent of the group. If 75 per cent of the pupils answering the first item correctly, answer all the easier questions, while 60 per cent of the pupils answering the second item correctly answer all the easier questions, then the first item is selected. P. M. Symonds[2] criticizes this method of selection as

1 Gerry, H. L.: "A Test of High School Chemistry." *Harvard Bulletin in Education No. 9*, Harvard University Press, 1924.
2 Symonds, P. M.: "Measurement in Secondary Education." p. 141.

being partially sound since the main criterion for selection of items is not difficulty alone but the correlation of the item with the scores of the whole test.

The correlation between forms A and B of the test is .76± .008. Correlations of the tests with other criteria such as teachers marks and the College Board examination results are as high as the correlation between the tests. The brevity of the tests (25 items) partially accounts for their not having a higher correlation. Some of the objectivity of the test has been lost by permitting the scorer a little leeway in deciding upon correct responses.

In 1923, two forms of [3]Rich's chemistry tests were published. These tests, like the Gerry tests, are of the scale type, but are different in that the cyclic principle of Rugg was applied in their construction. Each cycle of six questions consists of the following kinds of questions: thinking; memory; numerical; thinking; memory; and laboratory. As each kind of question is repeated in the next cycle there is a steady increase in difficulty from the beginning to the end of the test.

The items selected for the tests were taken from the range of items found in five representative texts, twenty-five examinations from College Board and Regents, and a number of state syllabi in chemistry. Each item selected appeared in at least two texts or in a text, an examination, and a syllabus.

The norms which are expressed as T-scores (method of McCall) are based upon the first 2040 pupils tested with the first two forms of the test.

In content, a strong feature of the test is the fact that thought questions occupy a place on equal footing with memory questions. The weakness of the test lies in the small amount of subject matter covered and in the opportunities afforded for guessing since all twenty-five questions are of the multiple-choice type.

S. R. Powers began work on the construction of his chemistry tests in 1920 and published them in 1924. His tests are achievement tests of the scale type. His criterion for the

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3 Rich, G. M.: "Rich's Chemistry Tests—Manual for Giving and Scoring." Public School Publishing Company, 1923.

selection of items as stated in his monograph[4] is that of difficulty. During the course of his study, Dr. Powers shows to what extent the items selected represent the subject matter of those chemistry texts and manuals which were representative in his study. The sampling of subject matter in his test is much more generous than in the cases of the two tests already discussed. Part I of his tests consists of 30 items of the multiple-choice type to test the range of information in chemistry. Part II consists of 37 items to test the pupil's ability to do tasks such as writing formulas and equations, naming chemical compounds, and solving numerical chemistry problems.

In the experimental forms of the test, the correlations between the different forms averaged .796. Correlations between the tests and teachers' marks ranged from $.54 \pm .04$ to $.78 \pm .04$.

J. W. Rauth and T. G. Foran published their chemistry tests in 1924.[5] Test I is designed to measure achievement in high school chemistry during the first semester while Test II is designed to measure achievement after the completion of two semesters' work. Test I possesses diagnostic values since the results of its use by the teacher should indicate the kinds of difficulties his pupils encounter in the four types of material contained in the test. Test II is designed to measure the efficiency of remedial instruction as well as achievement.

The selection of items for the test is based upon the analysis of several widely used chemistry textbooks. Norms have been determined in respect to medians and percentile scores.

The Glenn-Welton Instructional Tests in Chemistry[6] which were published in 1930 represent the results of experimental work carried on for a period of ten years. At the present time, these tests are by far the most comprehensive tests in the secondary school field. The number of tests contained in the booklet is 36, each of which covers one distinct important topic taught in a first course of chemistry. The types of questions

4 Powers, S. R.: "A Diagnostic Study of Subject Matter of High School Chemistry." *Columbia University Contributions to Education*, No. 149.

5 Rauth, J. W. and Foran, T. G.: "The Rauth-Foran Chemistry Test II." *The Catholic Educational Review*, Vol. XXII, No. 9, 546-550. Nov. 1924.

6 Glenn, E. R., and Welton, Louis E.,: "Instructional Tests in Chemistry." Teachers' Manual. World Book Company, 1930.

used in the tests are multiple-choice, completion, matching, brief-answer, and modified true-false questions.

The selection of items for the first experimental edition of the test was based upon the analysis of widely used high school chemistry text books and several representative college textbooks. Successive editions of the tests have been revised in the light of numerous supplementary investigations. For example, the selection of vocabulary questions was based upon several investigations in the technical vocabulary of chemistry. Investigations were also made on diagrams, numerical problems, and equations.

The authors of these tests checked the validity of the tests by comparing every question with three of the most recent and widely used textbooks. When new editions of the leading texts were published, revisions were made in the tests as the result of this and similar comparisons. Still other criteria used in these tests are correlation with teachers' marks and the revisions suggested by many chemistry teachers.

An examination of the tests readily reveals the fact that these tests are built for diagnosing pupils' difficulties. Since all the questions on a single unit such as oxygen, hydrogen, equations, valence, etc., are concentrated on such a small range of subject matter, the diagnosis of learning difficulties is possible. Furthermore, the questions are framed so as to reveal the kinds of errors pupils will make in answering questions on explanations of chemical phenomena, industrial processes, and the like.

The correlations given for the fourth edition of Forms A and B (the present series of tests is a revision of Form A) range from .71 to .88 for the thirty-six tests.

The function of the tests is to improve the teaching and learning of chemistry in high schools and colleges.

"Chemistry Drill Tests" have been constructed by F. B. Emery for the purpose of diagnosing class and individual difficulties in chemistry. Like the "Glenn-Welton Instructional Tests in Chemistry", they represent a series of tests, each of which is devoted to a single unit of subject matter. The construction of these tests is based upon Dr. Emery's experience in teaching chemistry and upon two years of experimentation with the tests

in the Harrison Technical High School, Chicago. These tests have not been standardized.

The final forms of the Persing Laboratory Chemistry Test[7] were completed in 1928. The selection of material for this test is based upon the analysis of laboratory manuals, laboratory guides, and direction sheets in high school chemistry. Only those items were chosen which were common to all the available manuals. A few other items representing difficulties pupils encounter in the laboratory were added. The items in the test are set up in the form of problems. No attempt has been made to scale the items of the test.

Although the test has been given to several thousand students, the data available represent the results in testing 1726 pupils. The correlations of reliability between Forms A and B are .881 and .887.

The function of the test is to measure achievement of pupils in laboratory technique in high school chemistry.

The "Columbia Research Bureau Chemistry Test"[8] was constructed by E. R. Jette, S. R. Powers, and B. D. Wood and standardized in 1928, when Form A of the chemistry test was given to about eight thousand high school seniors in Pennsylvania in the Pennsylvania study of the relation of secondary and higher education. The test is designed to measure achievement in chemistry in high schools and colleges.

The test contains over 200 items and requires 180 minutes of actual working time on the part of the students. On account of its length, the test is more reliable and valid than final high school chemistry examinations or the usual college entrance examinations. The coefficient of correlation computed by the Spearman-Brown formula is .87.

The selection of material for the tests is based upon the analysis of five widely used textbooks in elementary chemistry, two of which were written by authors of college texts and three of which were written by high school teachers.

In 1924 and 1925, G. D. Stoddard and J. Cornog of the State University of Iowa constructed Chemistry Aptitude and Chem-

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7 Persing, K. M.: "Testing Laboratory Technic in High School Chemistry." *Journal of Chemical Education*, Vol. 6, Nos. 7 and 8. July, 1929; 1321-1327.

8 Jette, E. R., Powers, S. R., and Wood, B. D.: "Columbia Research Bureau Chemistry Test." Manual of Directions.

istry Training Tests[9] for the Iowa Placement Examinations. These tests are designed to measure the training and aptitude of students for the work in the first year of college chemistry and to serve for the sectioning of classes on the basis of ability. The Chemistry Aptitude Test is designed to measure abilities directly related to success in college chemistry. The abilities tested are those of making simple arithmetic and algebraic computations and reading comprehension. The student's interest in chemistry is determined by the extent and accuracy to which he responds to questions concerning chemistry knowledge which he may have gained in various ways outside the school room. The function of the Chemistry Training Test is to measure the amount of subject matter retained by the student.

In the selection of items for the test by the analysis of high school and college chemistry texts, only those items were selected which, in the judgment of the teacher, were of importance for college work. During revision, items were retained on the criterion that the items discriminate those students who subsequently failed in the course from those who subsequently succeeded.[10]

The Iowa Placement Examinations were given in twenty-nine institutions offering engineering courses and in twenty-three other institutions not offering such courses. Two-thirds of all the students examined were enrolled as engineering students.

The number of students who took the Chemistry Aptitude and the Chemistry Training Tests is 5,917 and 1,716 respectively.

With the exception of the Glenn-Welton Instructional Tests in Chemistry, all the tests discussed thus far are the achievement type. Several of the achievement tests do possess some diagnostic functions, but to a minor degree. In the Rauth-Foran Chemistry Tests, the diagnostic function is operating in the series of items on the writing of symbols and formulas, in the exercise on the classification of elements, compounds, and mixtures, in the exercise on chemical principles, and in the questions on numerical problems. The diagnostic values of the

9 Hammond, H. P., and Stoddard, G. D.: "A Study of Placement Examinations." *University of Iowa Studies in Education*, Vol. IV, No. 7.

10 Stoddard, G. D.: "Iowa Placement Examinations." *University of Iowa Studies in Education*, Vol. III.

"Powers General Chemistry Test" appear in the exercises on the principle of valence, the writing of formulas, the writing of equations, the naming of compounds, and the solving of numerical problems. The diagnostic characteristics of the "Powers General Chemistry Test" have been shown by Julia S. Bennett in her study on pupil errors.[11] She has done this by giving the "Powers General Chemistry Test", Form B, to 1470 pupils in 24 schools. She and her co-workers studied the types of error made by these pupils in the writing of formulas and the writing of equations.

The writer, in the construction of his diagnostic test, has used as one of his criteria for validity a study of the types of error committed by pupils taking the test. This phase of the study differs from that of Miss Bennett on the following points: the present study is more comprehensive, since in addition to the tabulation of the exact errors and the types of error, the number of times each occurs, and the per cents of their occurrences are of the total number of pupils taking the test, are recorded. Miss Bennett studied only a portion af her 1470 cases, while the present writer investigated one hundred per cent of his 1208 cases. Furthermore, in the present study, types of error in valence, numerical problems, and the writing of ions, none of which were studied by Miss Bennett, are analyzed.

Aside from the diagnostic tests contained in the "Glenn-Welton Instructional Tests in Chemistry", there are no chemistry tests available whose primary function is diagnosis. The writer's proposed test differs from the others which have been described in this dissertation in that the exercises in one part of the test are arranged in steps based in part upon the analysis of errors made by the pupils in the preliminary testing and in part upon the analysis of the operations required in a given ability. In equations, for example, pupils had made errors in balancing equations, in valence, in writing molecules, in the formulas of reagents, and in the products of the reaction. Therefore, the series of exercises on equations were set up in such a

11 Bennett, Julia S.: "Pupil Errors in Chemistry." *Journal of Chemical Education*, IV, 45-57, January, 1927.
.....: "A Study of Pupil Errors in Chemistry." *Journal of Educational Research*, XIV, 275-283, November, 1926.

manner as to test each phase of the difficulty. The exercises on the writing and naming of formulas are constructed primarily on the principle that the pupils' errors are caused by a lack of knowledge of the principle and by failure to remember the name and formula of the fundamental compound in a series of compounds. In the exercises on writing formulas with valence given, the selection of items is based both upon the analysis of operations and upon the analysis of errors.

3. The Plan of Procedure

The first step in the construction of the test was to determine which high school chemistry textbooks are the most widely used in the secondary schools of the United States. This was accomplished by scanning the literature for studies in which investigations had been made in the determination of representative chemistry textbooks in use in the secondary schools of this country. Since 1916, investigations concerned with the use of chemistry texts have been undertaken by William H. Wiley[12], A. Silverman[13], E. E. Rademacher[14], H. L. Gerry[15], S. R. Powers[16], and L. V. Koos[17]. In Wiley's analysis of 72 questionnaire responses from cities located in 30 states of the United States, the ranks according to frequency of the first four authors of high school chemistry texts are Brownlee et al., McPherson and Henderson, Newell, and Hessler and Smith. The ranking order of the five outstanding authors in Silverman's questionnaire study of 971 high schools in Pennsylvania are Brownlee et al., McPherson and Henderson, Newell, Fuller, and Blanchard and Wade. Rademacher's questionnaire study on the State of Illinois gives the following rank order: Brownlee et al., McPherson and Henderson, Alexander Smith, and C. S. Dull. H. L. Gerry, in the construction of his chemistry test, found that approximately two thirds of the 55 cooperating schools used one or another of three authors: Brownlee et al.,

12 Wiley, W. H.: "Where Are We in Chemistry?" *School Science and Mathematics*, 17, 197-208, March, 1917.

13 Silverman, A.: "A Survey of High School Chemistry in Pennsylvania." *Science, N. S.*, 48, 179-182, August 23, 1918.

14 Rademacher, E. E.: "The Values of Valence and When to Teach It." *School Science and Mathematics*, Vol. 22, 362-367, April, 1922.

15 Gerry, H. L.: "A Test of High School Chemistry." *Harvard Bulletin in Education*, No. 9, p. 17-18, 1924.

16 Powers, S. R.: "A Diagnostic Study of the Subject Matter of High School Chemistry." *Teachers College Contributions to Education*, No. 149, p. 41.

17 Koos, L. V.: "The Junior College", Vol. II, p. 476, 1924.

Black and Connant, and Newell. S. R. Powers, during the construction of his test, found that Brownlee et al., McPherson and Henderson, and Dull were the representative authors of high school chemistry texts in the fifteen schools which cooperated with him.

From the widely used texts listed above, those by Brownlee et al., McPherson and Henderson, Dull, and Newell were chosen in the present investigation. Dull's text was selected because it appeared in the more recent investigations and Newell's was chosen because it was a text which was used by one of the schools in the present investigation. A fifth book, "Fundamentals of Chemistry" by Gray, Sandifur and Hanna, was also chosen because it happened to be in the writer's possession. The selection of this text was justified later by the results of a questionnaire study made by the writer. An analysis of the responses received from cities in every state in the Union with the exception of Nevada, shows that the Gray, Sandifur, and Hanna text ranks sixth in the order of frequency.

These five selected textbooks and their manuals were then analyzed in regard to subject matter on gases. The gases were selected on two criteria: namely, that they be found both in the textbooks and manuals and that the gas possess properties of the greatest diagnostic value. Thus not only are oxygen and hydrogen found in all five texts and manuals, but they have characteristic properties which are being tested. Ammonia occurs in all five texts and manuals, but was not selected because under certain conditions it will burn and under other conditions it will not burn. A more complete discussion of this point is given in Chapter II.

In the analysis of the five chemistry textbooks of those laws and theories which occurred in all the textbooks, only those directly related to the principle of valence, the writing of equations, and the solving of problems were selected.

All the equations occurring in three of the texts and their corresponding manuals (Brownlee et al., Dull, and Newell) were written down, classified, and tabulated as to frequency of occurrence. Equations of lower frequency which were best suited for the function were selected for the initial steps of equation writing. The less common equations were chosen and

changed slightly so that the chance for memory to operate was reduced to minimum. For the more difficult operations, equations of higher frequency were chosen temporarily. Their occurrence in the other two texts and manuals was then checked. If the equations occurred here they were then selected for the test.

An examination of the five chemistry textbooks showed that each author devoted some space to the discussion of principles of valence, nomenclature, and the writing of formulas.

The numerical problems occurring in the five chemistry textbooks were listed and classified into fifty-two individual types of problem. These fifty-two sub-types of problem were then reclassified into the general types as shown in Table I. The number of problems in each type and the per cent that number is of the total number of problems for a given text was then computed. These per cents were then averaged.

The types and sub-types of numerical problems were selected on the basis of two criteria: rank order of average per cents and the importance of interrelationships among the types and sub-types. Those selected were equation problems involving weights, equation problems involving volumes, those involving the use of the laws of Boyle and Charles, those involving the computation of formulas, and those requiring the calculation of the weight of a liter of gas.

The selection of items for the test was checked by comparing it with an analysis of College Entrance Board Examinations covering an eleven year period (1917-1927). In this analysis, the items in each of the questions in the twenty-two examinations were listed and classified. The number of times each type occurs and the per cent each list of items is of the total number of items was computed.

The next step in the procedure for establishing the validity of the material selected is to show that this subject matter is actually being taught in the chemistry classes of the secondary schools of the United States. With this point in mind, the writer interviewed twenty-five high school chemistry teachers in Philadelphia and its suburbs regarding the types of subject matter presented in class and laboratory work. The questions asked during these interviews were formulated into a question-

naire which was sent in June, 1930 to the school superintendents in two of the largest cities in each state of the Union. During September, 1930, the questionnaire was again sent out to school superintendents of one or two cities next larger in size in those states from which only one response or no response had been received. The tabulated results from 96 questionnaires representing every state in the Union, with the exception of Nevada, are shown in Tables XXI-XXIV and are fully discussed in Chapter II.

Towards the close of the present investigation, a check was made upon the textbook analysis by analyzing the same five textbooks and manuals on the basis of per cent of total space occupied by each topic. Since the returns from the questionnaires showed the presence of two new authors holding the second and third ranking positions and the presence of later editions of chemistry texts, these additional texts were analyzed. Tables were then constructed to show the per cent of total space occupied by each topic in the six ranking textbooks. In the case of the five texts and five manuals the ranking order was determined by averaging the per cents for the topics in the texts, manuals, and College Entrance Board Examinations. The same process was followed in the case of the six ranking textbooks. The comparison of the results of these analyses with the very first textbook study is presented and described in the next chapter.

After the completion of the very first analysis of chemistry texts and manuals, one form of the test was constructed and tried out in the writer's chemistry class. In the light of the results and the constructive criticism of the seminar group in secondary education, the test was revised and sent out in the spring of 1928 to one private and eight public schools located in Philadelphia and its suburbs and in western New Jersey. These tests were returned to the writer who then scored and analyzed them. As a result of this analysis, further revisions were made in this test and the second form of the test was constructed.

Both forms of the test were sent out in January, 1929 to twelve public schools, nine of which are located in Eastern Pennsylvania, two in New Jersey, and one in Maryland. These tests were given by the various teachers in the following man-

ner: around mid-years, each teacher gave one-half his class Form A and the other half, Form B. During April or May, the tests were given again so that those pupils who had been tested by Form A in January or February were then tested by Form B, and those who had been examined by Form B the first time were tested by Form A on the second occasion. According to this procedure, 624 pupils were examined by Form A and 584 pupils were examined by Form B.

As the tests which were given around mid-years were scored and analyzed, the writer observed that an improvement could be made by making minor changes in the set up and directions for two of the exercises. Accordingly, a short test (Form X) containing the desired revisions was constructed and given in three schools where 162 pupils took the tests. The tests were then analyzed in order to determine the effect of these changes upon the per cent of pupils answering each of the items correctly and also upon the types of error made by the pupils.

The writer corrected and scored all the test papers of each form whether the various cooperating teachers scored the papers or not. Any errors made in correction or scoring were corrected and checked during the different steps in the analysis of the papers. The steps in the analysis are as follows: the total number and per cent of pupils answering each item correctly were found for Forms A and B for the first time they were given and for the second time they were given and for the combination of the two testings. Part I of each test was analyzed in order to determine how many pupils and what per cents of pupils made scores of 4, 3, 2, 1, and 0 on each of the ten properties. The average per cents of correct responses for each of the ten properties of the four gases were then calculated. The number of pupils and the per cents of pupils making scores of 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, and 0 for each of the four gases were found together with the average per cents of correct responses for each of the four gases.[18] A further analysis of Part I was made by recording the number and per cent of ommissions in order to determine to what extent the directions for Part I had been followed by the pupils.

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18 For a complete explanation of these statements refer to the explanation of this analysis in Chapter III, section 2, and to Tables XXXIV-XXXIX.

The errors made by the pupils on each question in Part II of Forms A and B were analyzed and classified into types. The numbers and per cents of pupils making each type of error were computed and tabulated as shown in Tables XL-LVI, LXXIX-LXXXVIII. These data represent the types of error which were made at mid-years, near the end of the school term, and the combination of the two. The results of Form X were analyzed in the same manner.

The distribution of scores of Forms A and B for each of the testing periods and for the two periods combined were obtained by two methods: the quartile method as shown in Table XXVI and the percentile method as shown by Graphs I to VI inclusive.

Since the second textbook analysis showed the importance of percentage composition problems and since their exclusion could not be justified on the grounds of relationship to problems involving the computation of formulas, it was deemed necessary to try out this type of problem in a short test. This test was given in four schools, three in eastern Pennsylvania and one in New Jersey. This test was analyzed in the same manner as was Form X.

CHAPTER II

ESTABLISHING THE VALIDITY OF THE TESTS

1. Textbook Analysis and the Selection of Items

One of the first considerations in building a standardized or an unstandardized test is the criterion of validity. The proposed test will have little value as a measuring instrument if it does not measure adequately those traits, functions, or subjects which it was designed to measure. The first concern of the test builder is the choice of material to be used in the test. The builder may use one or more criteria in the choice of material. The criteria which have been used in the construction of tests are the criterion of extrinsic use, criterion of errors, a composite of textbooks, a composite of the requirements in courses of study, a composite of teachers' examinations, and the judgment of experts.[19]

The principal criteria for the selection of material in the construction of Form A and Form B are the criterion of errors and the analysis of textbooks. The criterion of errors is based upon previous studies made by the writer in his chemistry classes.[20] In the present investigation, an analysis of the types of error made by the pupils during the tryouts of the tests has been used as one of the principal criteria for showing the validity of the tests. Other criteria which have served as checks upon the material already selected are an analysis of the College Entrance Board Examinations (1917-1927), a course of study as proposed by the American Chemical Society,[21] questionnaire

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19 Symonds, P. M.: "Measurement in Secondary Education", pp.280-285.

20 Malin, J. E.: "Diagnosis by the Use of Science Tests in the Senior High School." *Bureau of Educational Measurements*, University of Pennsylvania, 1926. (Complete report of the study.)

.....: "Diagnosis by the Use of Science Tests in the Senior High School." *Schoolmen's Week Proceedings*, 212-222, 1926.

.....: "A Diagnostic Study of Students' Difficulties in Chemistry and the Effects of Application of Remedial Measures." Master's Thesis, University of Pennsylvania, 1927.

21 Committee of Chemical Education of the American Chemical Society: "Correlation of High School and College Chemistry." *Journal of Chemical Education*, Vol. 1, 87-99, May, 1924.

data collected by the Central Association of Science and Mathematics Teachers,[22] and the questionnaire data collected by the writer.[23]

The method of selection of representative chemistry textbooks has already been described in Chapter I. The five chemistry texts and their corresponding manuals which were analyzed are those written by Brownlee et al..[24] McPherson and Henderson,[25] C. E. Dull,[26] L. C. Newell,[27] and Gray, Sandifur, and Hanna.[28] These texts and their manuals were examined with respect to content on the gaseous elements and compounds. All the gases and their principal properties were listed. From this list, those gases which occur in both the texts and the manuals and which have the greater diagnostic values were chosen. The only exception to this principle of choice is that of the rare gases, helium and argon, which are not discussed in the manuals. These two gases were chosen because they possess a property which none of the other gases have, namely, the property of being inert. The presence of these two gases in Forms A and B increases their diagnostic value, since the pupils are given an opportunity to apply their knowledge of the meaning of inert in situations where they have not had an opportunity to observe the phenomenon in the laboratory. For example, if they know that inert gases will not interact with any reagent, they should be able to conclude that they will not support combustion or burn. Such gases as oxygen, hydrogen, nitrogen, carbondioxide, and chlorine were chosen for the test since they not only occur in all the texts and mannuals, but possess those properties which are commonly tested in the laboratory. Although the gas ammonia is fully discussed in each of the texts and is contained in the manuals as experiments, yet it was not chosen for the tests because its ability to burn varies under different conditions. Ordinarily, ammonia does not burn

22 Central Association of Science and Mathematics Teachers: "Minutes of the Chemistry Section." *School Science and Mathematics*, Vol. 20; 242-251; March, 1920.

23 See "Questionnaire Analysis" at the close of Chapter II.

24 Brownlee, Fuller, Hancock, Sohon, and Whitsit: "First Principles of Chemistry," Allyn and Bacon, 1915.

25 McPherson and Henderson: "A First Course in Chemistry." Ginn and Company, 1915.

26 Dull, C. E.: "High School Chemistry." Henry Holt and Company, 1925.

27 Newell, L. C.: "General Chemistry." D. C. Heath and Company, 1915.

28 Gray, C. W., Sandifur, C. W., and Hanna, H. J.: "Fundamentals of Chemistry." Houghton, Mifflin Company, 1926.

in air, but if the gas is very hot and sufficient oxygen is present, it will burn.

For the selection of the material on laws and theories, all were listed which occurred in the five textbooks. From this list, only those which were directly related to the mechanical fundamentals of the test and were found in all five textbooks were chosen. Those which were selected are the theory of ionization, the law of Charles, the law of Boyle, the law of multiple proportions, law of definite proportions, Gay Lussac's law of combining volumes, and law of conservation of matter. The theory of ionization is directly related to the principle of writing ions and ionic equations. The application of Boyle's law and Charles's law appears in the numerical problems which involve the use of formulas of these laws. The application of Gay Lussac's law appears in the solving of problems involving the use of gas equations. The law of definite proportions is directly related to those problems which involve the principle of percentage composition. The law of conservation of matter is exemplified in the writing of equations, since the sum of the weights on the one side of the equation is always equal to the sum of the weights on the other side of the equation. The relationship of the law of multiple proportions to numerical problems in which the formula or formulas are computed is shown in problems requiring the computation of two or more formulas having the same elements but in different proportions.

Each of the five chemistry texts devoted some space to the principles of valence, writing formulas, and nomenclature. Exercises for testing the pupils' understanding of the principle of valence were constructed as follows: Several common elements and radicals were selected and the valence of each was indicated by means of plus or minus charges. These elements and radicals were set down as incomplete formulas to be completed by the pupil by writing in the proper subscripts. In the selection of these elements and radicals, only those were chosen which would exemplify the different kinds of operations in the writing of formulas with valence and symbols given. For example, the possible cases are the writing of no subscripts, of one subscript, and of two subscripts. Another operation which is required in the case of some formulas is the use of the

smallest possible subscripts where larger subscripts quite naturally balance the total valence. For example, the total valence in the formula, MnO_2 balances when written as Mn_2O_4. In order to test the completeness of the pupil's concept of the principle of valence, still another operation is required in this exercise. It is the ability to find the valence when only one valence is known and two or more related formulas are given. An illustration of such a question is: If, in the list of the generalized chemical formulas A_2B, A_3C_2, and DC_2, B has a valence of 4, what is the valence of D? This type of question was placed in the test because the writer had found pupils making errors in valence in the writing of the products of completion equations of the double decomposition type. If the pupil had applied the principle of valence to the formulas on the left hand side of the equation, he would have computed the valence of the elements or radicals he did not know, and then would have used these valences on the right hand side of the equation.

A more complex situation for the writing of formulas is one in which no valence is given and one in which the principles of nomenclature operate. The selection of items for this exercise is based primarily upon the criterion of errors. In his first study[29] of types of error in the mechanical operations of high school chemistry, the writer found that a certain per cent of his pupils made errors in writing "ides" as "ites," "ates" as "ites," in valence, in the principle of valence, in molecular formulas, and in following directions. An example of writing "ides" as "ites" is the writing of the formula sodium chloride as that of sodium chlorite. In his second study[30] of the types of error in the writing of formulas, the same types were again present, together with new types such as those in writing the "hypo-ous" acids, "ic" acids, "per-ic" acids, "hypo-ite" salts, "per-ate" salts, and radicals. These types of error were the result of pupils not knowing the fundamantal formula for a series of acids and salts, of their lack of knowledge of the principle of nomenclature, of their failure to remember the valence

29 Malin J. E.: "Diagnosis by the Use of Science Tests in the Senior High School." *Bureau of Educational Measurements*, University of Pennsylvania, Table 7, 1926.

30 Malin, J. E.: "A Diagnostic Study of Students' Difficulties in Chemistry and the Effects of Application of Remedial Measures." Master's Thesis, University of Pennsylvania, 1927.

of certain elements and radicals, and of their incomplete understanding of the principle of valence. This list of errors can be classified into two general types: principle of nomenclature and principle of valence.

Since the principal difficulties in nomenclature are the principle of nomenclature and the knowing of the fundamental formula, the writer therefore composed an exercise on formula writing in which the fundamental formula to a series of formulas was given. Items in this series would, therefore, diagnose difficulties in the principle of nomenclature. Formulas in other series of compounds are also required in this exercise so that the pupil will be required to know both the principle and the fundamental formula, unless memory alone is responsible for his knowledge of the formula.

The selection of items for the exercise on the principle of nomenclature is based upon the writer's findings in the two previous studies mentioned above. The types of error made in naming formulas were practically the same as those made in writing formulas. The exercise with its series of items was set up according to the principles described in the preceding paragraph. These two exercises on nomenclature and formula writing also contain compounds outside the series of acids and salts just mentioned. These compounds are the acid salts, the oxides, and the hydroxides.

The choice of items in the exercises on the writing of equations is based upon two criteria: the criterion of errors as found in previous studies and the criterion of textbook analysis. The tests used in the writer's 1926 study were the "New Types of High School Chemistry Tests for Instructional Purposes," by E. R. Glenn and L. E. Welton, "Powers' General Chemistry Test," Forms A and B, and "Gerry's Tests of High School Chemistry," Forms A and B. During the 1927 study, "Powers General Chemistry Test," Form B was used, together with objective tests of the writer's construction. The types of error made in equation writing in the two studies are the same. These types are as follows: pupils did not know the product of a reaction; did not know the formula for a given reagent; failed to follow directions; made errors in balancing the equation; made errors in valence; failed to write the correct molecular formulas; and

omitted equations. From a study of these errors, the writer analyzed the process of equation writing into several steps. The simplest step is the balancing of equations in which all the formulas are given in the equation. The second step is the writing of completion equations of the double decomposition type. A sample is given which shows that there are only two products, and that the metals and the radicals of the two reagents have exchanged places. The pupil is required to perform two operations: the writing of the two formulas for the products and the balancing of the equation. Another step is the writing of correct molecular formulas in the equation. In this case, the equations given in the exercise contain all the formulas in the reaction. It is only necessary for the pupil to write in the necessary subscripts to make molecular formulas of those which are not molecular, and then balance the equation. The next step in equation writing is to complete an equation in which the formulas of the reagents are given. This requires the writing of the correct formulas of the products and the balancing of the equation. The last and most difficult step is the writing of an entire equation in which the pupil is given the names of the reagents and nothing else. A more difficult subtype of this kind of equation is one in which the names of the reagents are not given. An example of this type is: "Write an equation for the preparation of nitric acid."

When the writer had decided to test these various steps in equation writing, the next operation was to analyze the equations in the textbooks and manuals. The equations in three of the texts and their corresponding manuals were listed, tabulated as to frequency, and classified. The various types represented in the texts and manuals are decomposition, synthesis, single displacement, metathesis or double decomposition, metathesis and decomposition, oxidation and reduction, ionic, and word equations. The formulas in the equations in the three texts and in the remaining two as well are written in the molecular form.

From the types of reactions stated above, the following were selected to represent the analytical steps in equation writing: synthesis, single displacement, double decomposition, metathesis and decomposition, ionic, and molecular equations. No word equations were selected, because word equations are only

used in the early learning stage until the pupil learns how to write formulas. No equations of the oxidation and reduction type were chosen for the following reasons: in the first place, these equations are very difficult, as shown by the data presented in Dr. Powers' study of high school chemistry subject matter.[31] He shows that such equations as $H_2S + H_2O_2$, $Cu + HNO_3$ (conc.), $Cu + H_2SO_4$ (hot conc.), and $HNO_3 + HCl$ are answered correctly by 24.1, 16.6, 12.8, and 10.3 per cent of the pupils respectively. In the second place, the types of error made by the pupils in oxidation and reduction equations in the 1927 study were the same types as made in other types of equations. The greatest number of errors occurred in the products of the reaction and as omissions. In the third place, oxidation and reduction occur in the single displacement type of equation, which is represented in the test.

Equations for the simpler steps in equation writing were chosen from those equations having the lower frequency of occurrence. Some of these selected equations were changed slightly so that the functioning of memory would be reduced to the minimum. For example, the reaction of $AlCl_3$ with NH_4OH occurs only once in the three texts and the three manuals. This equation was placed in the exercise on balancing of equations and KOH was substituted for NH_4OH. In the case of the writing of completion and entire equations, equations having higher frequency were chosen. Their presence in the two other texts and manuals was checked before placing them in the tests. To illustrate, the equations $Zn + H_2SO_4$ and $Zn + HCl$ had frequencies of 12 and 5 respectively in the three texts and their manuals. This general method of generating hydrogen by the action of an acid upon a metal was found in all five texts and their corresponding manuals.

The analysis of the textbook numerical problems is shown in Table I, which reads as follows: 39 problems or 37.2 per cent of all the problems in textbook A are equation problems; 66 problems, or 52 per cent of all the problems in textbook B, are equation problems. The average per cent of equation problems

31 Powers, S. R.: "A Diagnostic Study of the Subject Matter of High School Chemistry." *Teachers College Contributions to Education,* No. 149, page 22.

TABLE I.

NUMBER AND PER CENT OF TYPES OF PROBLEM OCCURRING IN THE FIVE SELECTED TEXTBOOKS

TYPE	TEXTBOOKS										Average Per Cent
	A		B		C		D		E		
	Number of Problems	Per Cent of Problems	Number of Problems	Per Cent of Problems	Number of Problems	Per Cent of Problems	Number of Problems	Per Cent of Problems	Number of Problems	Per Cent of Problems	
Equation	39	37.2	66	52.0	28	46.6	79	34.7	68	59.7	46.0
Law of Boyle & Charles	18	17.2	17	13.3	6	10.1	24	10.5	16	14.1	13.0
Miscellany	8	7.6	18	14.1	4	6.7	39	17.0	11	9.7	11.0
Per cent	7	6.7	4	3.1	10	16.6	31	13.5	3	2.6	8.5
Percentage Composition	5	4.7	6	4.8	6	10.1	25	10.9	8	7.1	7.5
Computing the formula	13	12.4	13	10.2	5	8.3	12	5.2	0	.0	7.2
Finding the weight of 1 liter	8	7.6	3	2.4	1	1.7	1	.4	7	6.1	3.6
Metric	7	6.7	0	.0	0	.0	18	7.9	1	.9	3.1
Total	105	100.1	127	99.9	60	100.1	229	100.1	114	100.2	100.1

TABLE II.

NUMBER AND PER CENT OF SUB-TYPES OF EQUATION PROBLEM OCCURRING IN THE FIVE SELECTED TEXTBOOKS

SUB-TYPE	TEXTBOOKS										Average Per Cent
	A		B		C		D		E		
	Number of Problems	Per Cent of Problems	Number of Problems	Per Cent of Problems	Number of Problems	Per Cent of Problems	Number of Problems	Per Cent of Problems	Number of Problems	Per Cent of Problems	
Equation problems involving:											
Weights	19	18.1	29	22.4	15	25.0	39	17.0	41	36.0	23.7
Volume and weight	10	9.5	25	19.8	6	10.0	18	7.9	14	12.3	11.9
Per cent purity	5	4.8	1	.8	5	8.3	11	4.8	7	6.1	5.0
Volumes	5	4.8	10	7.9	2	3.3	2	.9	6	5.2	4.4
Computing atomic weight	0	.0	1	.8	0	.0	9	3.9	0	.0	.9
Total	39	37.2	66	51.7	28	46.6	79	34.5	68	59.6	45.9

in the five textbooks is 46. This table represents the reclassification of 52 individual types of problem into general types.

Table II presents the analysis for the sub-types of equation problems and is read in the same manner as Table I. The selection of the types and sub-types of problem for the test is based upon two criteria: the rank order of average per cents and the value of inter-relationships. Since the equation type of problem is the most common one, two of its sub-types were selected, the one involving the use of volumes and the one involving the use of weights. The weight equation problem was chosen because its main principle is common in two other sub-types and because it has a higher frequency of occurrence. The sub-type involving volumes was chosen because it introduces a new principle into the equation type of problem, namely, the comparing of volume ratios with molecular ratios. The type of question involving the finding of the weight of one liter of gas, though low in rank in Table I, was selected because of its close relationship to equation problems involving the use of volume and weight. Problems of this type, when solved by one method, require the finding of the weight of one liter of the gas. The problems on Boyle's law and Charles's law were included in the tests on the criterion of rank. Problems involving the computation of formulas were included in the tests, but none on percentage composition was chosen because of its relationship to problems on the computation of formulas. Since the problems on formulas in the tests do not fully exemplify the principle of percentage composition, the exclusion of percentage composition problems is not justified. Therefore, the percentage composition type will be included in the final forms of the test.

Since the first examination of the textbooks was not done on the basis of per cent of space actually occupied by each topic, it was decided to check the results of the first analysis by performing a second analysis on the per cent of space basis.

In this recheck of the content of the text books, the page was used as the unit of count. Twenty pages of the texts and 15 pages of the manuals were sampled at random to determine the number of lines to a page and the number of words to a line. The average number of lines to a page for a given text-

book was used as the page unit for that book. If textbook A averaged thirty lines to a page and a certain topic occupied six lines, the space devoted to the topic is two-tenths of a page. Prefaces, tables of contents, summaries, suggestions to teachers and pupils, appendices, and indices are not included in this analysis. All pages containing diagrams and illustrative material were given the same weight as the printed page. Since many of the pages in the texts contain equations, and since equations are one of the elements being analyzed, the space occupied by equations in a given topic was always subtracted from the space occupied by the topic.

The five original texts and their corresponding manuals were analyzed in the manner described above. Since the results of the writer's questionnaire had shown the prominence of two new texts and the presence of the later editions of two of the five original texts, these were analyzed, too. The tables on book analysis which have been constructed are in two series. those representing the analysis of the original five texts and those representing the analysis of the present first six ranking texts.

Table III, which shows the analysis of the gaseous elements and compounds, reads as follows: on the topic "Oxygen." textbook A devotes 15.4 pages; B, 9.2 pages; and so on. The total number of pages, the average number of pages, and the per cent of total space devoted to each topic are given in the last three columns. Table IV for the six textbooks is read in the same manner. Table V shows the amount of space devoted to each gas in each of the manuals. Since the data on the five textbooks are so similar to the data on the six textbooks, and since the six textbooks represent a more recent ranking of chemistry textbooks, the remaining tables on the analysis of the five texts are placed in the Appendix.

Table VI shows the per cent of space devoted to the subtopics under gases. Tables VII-X present the material for the analysis of laws and theories, of equations, of problems, and of the sub-types of problems respectively.

Table XI shows how the gases are ranked on the basis of the analysis of textbooks, manuals, and College Entrance Board Examinations. The table reads as follows: all six textbooks and all the five manuals contain material on oxygen. The per cent

TABLE III.

TOTAL NUMBER AND PER CENT OF PAGES DEVOTED TO GASEOUS ELEMENTS AND COMPOUNDS IN THE FIVE SELECTED TEXTBOOKS

TOPIC	TEXTBOOKS					Total No. of Pages	Average No. of Pages	Per Cent of Total Space
	A	B	C	D	E			
Oxygen	15.4	9.2	12.2	10.2	4.9	51.9	10.38	2.39
Ozone	1.9	1.0	.8	.3	.0	4.0	.80	.18
Hydrogen	7.5	9.1	6.6	6.6	3.3	33.1	6.62	1.52
Chlorine	7.1	7.3	4.3	3.3	2.9	24.9	5.18	1.15
Hydrogen chloride	.7	4.2	1.9	1.6	1.0	9.4	1.88	.43
Fluorine	.2	1.2	1.2	1.3	.6	4.5	.90	.21
Hydrogen bromide	.3	.4	.3	.1	.1	1.2	.24	.06
Hydrogen iodide	.3	.0	.2	.0	.0	.5	.10	.02
Nitrogen	5.0	5.2	5.3	4.5	1.7	21.7	4.34	1.00
Ammonia	6.7	4.8	4.0	4.3	1.2	21.0	4.20	.97
Nitric oxide	1.3	.3	.6	.3	.3	2.8	.56	.13
Nitrous oxide	1.4	.4	.7	.1	.1	2.7	.44	.12
Nitrogen dioxide	.4	.7	.4	.3	.1	1.9	.38	.09
Nitrogen tetroxide	.1	.0	.6	.0	.1	.8	.16	.04
Carbon dioxide	3.7	4.6	2.4	1.8	3.9	16.4	3.28	.76
Carbon monoxide	1.6	2.7	.9	1.2	.7	7.1	1.42	.33
Methane	.3	1.1	.5	1.1	.4	3.4	.68	.16
Acetylene	2.8	.3	1.0	1.2	.7	6.0	1.20	.28
Ethylene	.4	.2	.0	.3	.2	1.1	.22	.05
Cyanogen	.2	.0	.1	.2	.0	.5	.10	.02
Hydrogen sulphide	2.2	2.7	2.5	1.0	1.1	9.5	1.90	.44
Sulphur dioxide	3.4	4.4	1.2	1.4	1.2	11.6	2.32	.53
Helium	1.0	.4	.6	.3	.5	2.8	.56	.13
Argon	1.1	.6	.1	.8	.0	2.6	.52	.12
Phosphine	.0	.0	.4	.1	.0	.5	.10	.02
Arsine	.0	.0	.9	.1	.0	1.0	.20	.05
Phosgene	.3	.0	.0	.0	.3	.6	.12	.03
Chloro-picrin	.3	.0	.0	.0	.3	.6	.12	.03
Neon	.2	.1	.1	.1	.0	.5	.10	.02
Total	65.8	60.9	49.8	42.5	25.6	244.6	49.02	11.28

TABLE IV.

TOTAL NUMBER AND PER CENT OF PAGES DEVOTED TO GASEOUS ELEMENTS AND COMPOUNDS IN SIX SELECTED TEXTBOOKS

TOPIC	TEXTBOOKS						Total No. of Pages	Average No. of Pages	Per Cent of Total Space
	A	B	C	D	E	F			
Oxygen	12.4	14.9	9.7	12.3	15.4	4.9	69.6	11.60	2.34
Ozone	1.0	1.8	.8	.8	1.9	.0	6.3	1.05	.21
Hydrogen	9.4	10.2	9.2	7.8	7.5	3.3	47.4	7.90	1.59
Chlorine	8.6	5.6	2.3	5.2	7.1	2.9	31.7	5.28	1.06
Hydrogen chloride	3.9	4.5	2.4	1.7	.7	1.0	14.2	2.37	.48
Fluorine	1.6	1.3	.7	1.0	.2	.6	5.4	.90	.18
Hydrogen bromide	.2	.2	.3	.2	.3	.1	1.3	.22	.04
Hydrogen iodide	.2	.0	.2	.2	.3	.0	.9	.15	.03
Nitrogen	2.8	5.2	4.1	4.0	5.0	1.7	22.8	3.80	.77
Ammonia	3.1	6.3	5.9	2.7	6.7	1.2	25.9	4.32	.87
Nitric oxide	.4	.6	.4	.4	1.3	.3	3.4	.57	.11
Nitrous oxide	1.0	1.0	.9	.6	.9	.1	4.5	.75	.15
Nitrogen dioxide	.6	.5	.6	.5	.4	.1	2.7	.45	.09
Nitrogen tetroxide	.3	.1	.2	.2	.1	.1	1.0	.17	.03
Carbon dioxide	5.6	5.6	10.3	2.8	3.7	3.9	31.9	5.32	1.07
Carbon monoxide	2.4	2.3	3.1	1.1	1.6	.7	11.2	1.87	.38
Methane	.3	1.5	.2	.5	.3	.4	3.2	.53	.11
Acetylene	1.4	1.5	1.1	1.4	2.8	.7	8.9	1.48	.30
Ethylene	.2	.0	.0	.2	.4	.2	1.0	.17	.03
Cyanogen	.0	.1	.0	.1	.2	.0	.4	.07	.01
Hydrogen sulphide	1.8	4.1	1.7	1.9	2.2	1.1	12.8	2.13	.43
Sulphur dioxide	2.4	6.0	3.3	1.2	3.4	1.2	17.5	2.92	.59
Helium	.6	1.1	1.5	.6	1.0	.5	5.3	.88	.18
Argon	.7	1.1	.7	.4	1.1	.8	4.8	.80	.16
Phosgene	.0	.4	.0	.0	.3	.3	1.0	.17	.03
Chloro-picrin	.0	.4	.0	.0	.3	.3	1.0	.17	.03
Neon	.1	.1	.1	.1	.2	.1	.7	.13	.02
Total	61.0	76.4	59.7	47.9	65.3	26.5	336.8	56.17	11.29

TABLE V.

TOTAL NUMBER AND PER CENT OF PAGES DEVOTED TO GASEOUS ELEMENTS AND COMPOUNDS IN THE FIVE SELECTED MANUALS

TOPIC	MANUALS					Total Number of Pages	Average Number of Pages	Per Cent of Total Space
	A	B	C	D	E			
Oxygen	2.1	2.1	3.8	3.0	2.4	13.4	2.68	.62
Ozone	.9	.0	.0	.0	.0	.9	.18	.04
Hydrogen	3.3	4.8	3.6	5.4	2.2	19.3	3.86	.89
Chlorine	1.3	1.6	2.1	2.8	2.4	10.7	2.14	.49
Hydrogen chloride	1.8	1.4	1.7	1.4	.7	7.0	1.40	.32
Hydrogen bromide	.3	.2	.2	.2	.1	1.0	.20	.05
Hydrogen iodide	.2	.0	.2	.3	.0	.7	.14	.03
Nitrogen	1.1	.8	2.2	1.1	1.7	6.9	1.38	.32
Ammonia	1.5	2.0	2.7	2.5	1.1	9.8	1.96	.45
Nitric oxide	1.2	.4	1.4	1.6	.0	4.6	.93	.21
Nitrous oxide	1.5	.5	.0	.0	.0	2.0	.40	.09
Nitrogen dioxide	.1	.1	.2	.3	.0	.7	.14	.03
Carbon dioxide	1.3	.9	3.6	2.7	2.4	10.9	2.18	.50
Carbon monoxide	.0	1.0	2.9	1.6	.0	5.5	1.10	.25
Methane	.0	.5	.0	.8	.5	1.8	.36	.08
Acetylene	.0	.2	.0	.0	.6	.8	.16	.04
Hydrogen sulphide	1.6	1.2	1.1	1.2	1.0	6.1	1.22	.28
Sulphur dioxide	1.2	1.0	3.6	.0	.9	6.7	1.34	.31
Total	19.9	18.7	29.3	24.9	16.0	108.8	25.01	5.00

TABLE VI

TOTAL NUMBER AND PER CENT OF PAGES DEVOTED TO THE SUB-TOPICS IN GASES IN THE SIX SELECTED TEXTBOOKS

Sub-Topic	Number of Pages	Per Cent of Total Space
Occurrence	18.8	.61
Preparation	88.7	2.98
Properties	87.9	2.95
Uses	73.9	2.48
Miscellany	67.5	2.27
Total	336.8	11.29

TABLE VII.

TOTAL NUMBER AND PER CENT OF PAGES DEVOTED TO LAWS AND THEORIES IN THE SIX SELECTED TEXTBOOKS

TOPIC	TEXTBOOKS						Total No. of Pages	Average No of Pages	Per Cent of Total Space
	A	B	C	D	E	F			
Principle of Valence	2.0	4.0	5.0	4.0	4.8	3.2	23.0	3.83	.77
Theory of Valence	.0	..0	1.3	1.8	1.8	.0	4.9	.82	.16
Electron Theory	10.0	4.5	3.0	6.7	.0	7.5	31.7	5.28	1.06
Theory of Ionization	12.0	10.2	12.5	5.7	11.0	4.4	55.8	9.30	1.87
Law of Dulong & Petit	.0	.0	.0	.0	.0	.0	.0	.00	.00
Law of Conservation of Matter	.4	1.0	.8	.3	.6	.3	3.4	.57	.11
Law of Conservation of Energy	.0	.0	.2	.4	.4	1.0	2.0	.33	.07
Law of Definite Proportions	.3	.3	.7	.4	.4	.6	2.7	.45	.09
Law of Multiple Proportions	.3	1.3	.6	.6	.7	.8	4.3	.72	.14
Gay Lussac's Law of Volumes	1.0	2.0	1.4	.7	.6	.7	6.4	1.07	.21
Henry's Law	.4	.3	.2	.3	.3	.0	1.5	.25	.05
Avagadro's Hypothesis	2.7	2.4	2.7	.3	2.6	1.2	11.9	1.98	.40
Law of Charles	2.9	3.4	2.6	2.4	2.4	1.0	14.7	2.45	.49
Law of Boyle	2.6	2.8	1.1	1.9	3.4	1.0	12.8	2.13	.43
Law of Mass Action	4.7	.3	1.9	2.0	2.4	3.0	14.3	2.38	.48
Law of Berthollet	3.5	.0	1.8	1.8	1.3	4.0	12.4	2.07	.42
Periodic Law	7.0	7.5	4.9	5.5	5.6	1.5	32.0	5.33	1.07
Law of Octaves	.2	.0	.0	.0	.2	.0	.4	.07	.01
Atomic Numbers	3.7	1.0	3.6	1.6	2.3	.0	12.2	2.03	.41
Atomic Theory	2.5	2.7	5.5	2.0	2.5	.4	15.6	2.60	.52
Kinetic Molecular Theory	.0	3.0	1.0	.7	1.0	2.0	7.7	1.28	.26
Phlogiston Theory	.0	.0	.0	.3	.0	.4	.7	.12	.02
Combining Weights	.0	.0	1.2	.3	1.8	.1	3.4	.57	.11
Principle of Nomenclature	.7	3.0	1.4	1.3	1.8	1.0	9.2	1.53	.31
Total	56.9	49.7	53.4	41.0	47.9	34.1	283.0	47.16	9.46

TABLE VIII.

TOTAL NUMBER AND PER CENT OF PAGES DEVOTED TO DIFFERENT TYPES OF EQUATION IN THE SIX SELECTED TEXTBOOKS

TYPE	TEXTBOOKS						Total No. of Pages	Average No. of Pages	Per Cent of Total Space
	A	B	C	D	E	F			
Word	.9	.8	.7	.3	1.0	1.3	5.0	.83	.17
Decomposition	1.4	1.1	1.2	1.2	1.1	1.0	7.0	1.67	.24
Synthesis	2.9	1.8	2.1	1.3	1.7	2.7	12.6	2.10	.42
Single Displacement	1.9	1.2	1.2	.8	1.0	.3	6.4	1.07	.21
Metathesis	2.7	1.8	2.4	2.3	3.5	4.5	17.2	2.87	.58
Metathesis & Decomposition	.6	.4	.3	.4	1.2	1.4	4.3	.72	.14
Oxidation & Reduction	3.	1.8	1.8	2.1	2.6	3.0	15.1	2.52	.51
Ionic	2.1	1.4	.7	.5	1.2	1.9	7.8	1.30	.26
Total	16.3	10.3	10.5	8.9	13.3	16.1	75.4	13.08	2.53

TABLE IX.

TOTAL NUMBER AND PER CENT OF PAGES DEVOTED TO PROBLEMS IN THE SIX SELECTED TEXTBOOKS

TYPE	TEXTBOOKS						Total No. of Pages	Average No. of Pages	Per Cent of Total Space
	A	B	C	D	E	F			
Metric	.0	.0	.0	.0	.5	.1	.6	.10	.02
Equation	9.3	11.3	11.4	9.0	6.7	7.0	54.7	9.12	1.83
Combining volumes	.3	.6	.1	.1	.3	.2	1.6	.27	.05
Equivalent weight	.2	.1	.1	.0	.2	.0	.6	.10	.02
Gram-molecular weight	.0	.1	.0	.0	.0	.0	.1	.02	.003
M. W. from atomic weights	.1	.0	.3	.3	.0	.2	.9	.15	.03
M.W. from depression of freezing point	.0	.0	.0	.0	.1	.0	.1	.02	.003
M.W. from Sp.Gr. of the gas	.2	.8	.0	.0	.0	.0	1.0	.17	.03
M.W. from weight of volume	.5	.8	1.0	.3	.8	.0	3.4	.57	.11
Percentage of composition	2.0	2.9	2.9	1.5	1.1	.7	11.1	1.85	.37
Per cent	.2	.2	.8	2.3	.6	.6	4.7	.78	.16
Compute formula	3.2	1.6	2.6	1.1	3.8	.0	12.3	2.05	.41
Compute number of atoms	.1	.0	.0	.0	.0	.0	.1	.02	.003
Compute weight of 1 liter of gas	1.0	.1	.3	.3	.8	.7	3.2	.53	.11
Reduction of Vol. to weight	.1	.1	.0	.4	.1	.0	.7	.17	.02
Reduction of weight to Vol.	.2	.3	.1	1.0	.1	.1	1.8	.30	.06
Find Sp.Gr. of gases (to air, to hydrogen, to oxygen)	.6	1.0	.2	.0	.3	.1	2.2	.37	.07
Density of solids & liquids	.1	.0	.0	.1	.0	.4	.6	.10	.02
Laws of Boyle and Charles	5.7	4.3	4.8	3.6	4.8	2.4	25.6	4.27	.86
Density and pressure	.2	.0	.0	.0	.0	.0	.2	.03	.01
Alkalimetry & acidmetry	.0	.2	.7	.0	.0	.0	.9	.15	.03
Solubility of gases	.0	.0	.0	.0	.0	.1	.1	.02	.003
Calories	.0	.0	.1	.6	.0	.0	.7	.12	.02
Heat of combustion	.0	.0	.1	.1	.0	.2	.4	.07	.01
Carats (gold)	.0	.0	.1	.0	.0	.0	.1	.02	.003
Proportion	.0	.0	.0	.0	.0	.1	.1	.02	.003
Ratio	.0	.0	.1	.6	.0	.0	.7	.12	.02
Find valence	.0	.0	.3	.0	.0	.0	.3	.05	.01
Henry's Law	.0	.0	.0	.0	.0	.0	.0	.00	.00
Find atomic weight	.2	.2	.7	.1	.0	.0	1.2	.20	.04
Miscellany	.1	.4	.1	.4	.0	.1	1.1	.18	.04
Total	24.3	25.0	26.8	21.8	20.2	13.0	131.1	21.94	3.73

TABLE X.

TOTAL NUMBER AND PER CENT OF PAGES DEVOTED TO THE SUB-TYPES OF PROBLEM IN THE SIX SELECTED TEXTBOOKS

SUB-TYPE	TEXTBOOKS						Total No. of Pages	Average No. of Pages	Per Cent of Total Space
	A	B	C	D	E	F			
Equationproblemsinvolving Weights	5.8	5.9	5.0	5.9	3.0	3.7	29.3	4.88	.98
Weights & per cent of ... purity	.5	1.2	1.2	1.1	1.0	.9	5.9	9.70	.20
Volume and weight	1.6	3.0	3.3	1.3	1.5	1.4	12.1	2.02	.41
Volumes	1.3	.9	1.4	.7	1.2	.8	6.3	1.05	.21
Computing atomic weight	.0	.2	.2	.0	.0	.0	.4	.07	.01
Volume, weight and per cent of purity	.1	.1	.3	.0	.0	.2	.7	.12	.02
Total	9.3	11.3	11.4	9.0	6.7	7.0	54.7	9.12	1.83
Percentage composition computed:									
From the formula	1.4	2.5	2.4	1.0	1.1	.6	9.0	1.50	.30
From the weight of constituents	.6	.4	.5	.5	.0	.1	2.1	.35	.07
Total	2.0	2.9	2.9	1.5	1.1	.7	11.1	1.85	.37
Per cent problems involving:									
Finding weights	.1	.1	.7	1.7	.6	.6	3.8	.63	.13
Finding volumes	.0	.0	.0	.6	.0	.0	.6	.10	.02
Finding per cent composition by volumes	.0	.1	.0	.0	.0	.0	.1	.02	.003
Per cent of element in ... ore to be expressed as per cent of oxide	.0	.0	.1	.0	.0	.0	.1	.02	.003
Finding profit & loss	.1	.0	.0	.0	.0	.0	.1	.02	.003
Total	.2	.2	.8	2.3	.6	.6	4.7	.78	.16
Formula:									
Computing the simple formula	.4	.0	2.0	.7	3.1	.0	6.2	1.03	.21
Computing the true formula	2.8	1.6	.6	.4	.7	.0	6.1	1.02	.20
Total	3.2	1.6	2.6	1.1	3.8	.0	12.3	2.05	.41

TABLE X.—*continued*

TOTAL NUMBER AND PER CENT OF PAGES DEVOTED TO THE SUB-TYPES OF PROBLEM IN THE SIX SELECTED TEXTBOOKS

SUB-TYPE	TEXTBOOKS						Total No. of Pages	Average No. of Pages	Per Cent of Total Space
	A	B	C	D	E	F			
Laws of Boyle & Charles									
Boyle	2.1	.7	1.1	.6	.7	.4	5.6	.93	.19
Charles	.8	.9	1.0	1.2	.7	.5	5.1	.85	.17
Boyle and Charles	.6	1.5	.9	.6	1.4	1.5	6.5	1.08	.22
Boyle & Charles with corrections	2.2	1.2	1.8	1.2	1.7	.0	8.1	1.35	.27
Boyle & Charles, find Wt.	.0	.0	.0	.0	.3	.0	.3	.05	.01
Total	5.7	4.3	4.8	3.6	4.8	2.4	25.6	4.27	.86
Alkalimetry & Acidmetry									
Finding weight of solute	.0	.2	.4	.0	.0	.0	.6	.10	.02
Finding normality	.0	.0	.2	.0	.0	.0	.2	.03	.01
Finding concentration	.0	.0	.1	.0	.0	.0	.1	.02	.003
Finding volume	.0	.0	.0	.0	.0	.0	.0	.00	
Total	.0	.2	.7	.0	.0	.0	.9	.15	.03
Computing atomic weight									
From weight of volume	.0	.0	.0	.0	.0	.0	.0	.00	.00
From density & per cent composition	.0	.0	.2	.1	.0	.0	.3	.05	.01
From percent composition M.W., & number of atoms	.1	.0	.0	.0	.0	.0	.1	.02	.003
From specific heat and atomic weights	.0	.0	.0	.0	.0	.0	.0	.00	.00
From M.W. & per cent composition	.0	.0	.5	.0	.0	.0	.5	.08	.02
From M.W. & atomic Wt.	.1	.0	.0	.0	.0	.0	.1	.02	.003
From per cent composition & one atomic Wt.	.0	.2	.0	.0	.0	.0	.2	.03	.01
Total	.2	.2	.7	.1	.0	.0	1.2	.20	.04
Density of solids & liquids									
Finding density	.0	.0	.0	.0	.0	.4	.4	.07	.01
Finding volume	.0	.0	.0	.0	.0	.0	.0	.00	.00
Finding weight	.1	.0	.0	.1	.0	.0	.2	.03	.01
Total	.1	.0	.0	.1	.0	.4	.6	.10	.02

TABLE X.—*continued*

NUMBER AND PER CENT OF PAGES DEVOTED TO THE SUB-TYPES OF PROBLEMS IN THE SIX SELECTED TEXTBOOKS

SUB-TYPE	TEXTBOOKS						Total No. of Pages	Average No. of Pages	Per Cent of Total Space
	A	B	C	D	E	F			
Miscellaneous problems involving:-									
Finding weight of solvent	.0	.1	.0	.0	.0	.0	.1	.02	.003
Weight of air over given area	.1	.0	.0	.0	.0	.0	.1	.02	.003
Use of tables	.0	.1	.0	.3	.0	.0	.4	.07	.01
Addition of weights	.0	.1	.0	.0	.0	.0	.1	.02	.003
Reduction of Centigrade readings to Fahrenheit	.0	.0	.0	.1	.0	.0	.1	.02	.003
Reduction of Centigrade readings to Absolute	.0	.1	.0	.0	.0	.0	.1	.02	.003
Finding length, shape changed, volume constant	.0	.0	.0	.0	.0	.1	.1	.02	.003
Finding cost of composite, ratios, and price per ingredient given	.0	.0	.1	.0	.0	.0	.1	.02	.003
Total	.1	.4	.1	.4	.0	.1	1.1	1.80	.04

TABLE XI.

THE RANKING OF THE GASES FROM THE ANALYSIS OF COLLEGE ENTRANCE BOARD EXAMINATIONS AND SIX SELECTED TEXTBOOKS AND FIVE SELECTED MANUALS

TOPIC	No. of Books Containing the Topic		Per Cent of Total Space Devoted to the Topic in the		Per Cent of Total No. of College Entrance Board Questions	Average Per Cent	Rank
	Texts	Manuals	Texts	Manuals			
Oxygen	6	5	2.34	.62	.56	1.17	1
Hydrogen	6	5	1.59	.89	.45	.98	2
Ammonia	6	5	.87	.45	1.06	.79	3
Chlorine	6	5	1.06	.49	.78	.78	4
Carbon dioxide	6	5	1.07	.50	.50	.69	5
Nitrogen	6	5	.77	.32	.34	.48	6
Carbon monoxide	6	3	.38	.25	.73	.45	7
Hydrogen sulphide	6	5	.43	.28	.56	.42	8
Sulphur dioxide	6	4	.59	.31	.17	.36	9
Hydrogen chloride	6	5	.47	.32	.11	.30	10
Nitric oxide	6	4	.11	.21	.39	.24	11
Nitrous oxide	6	2	.15	.09	.34	.19	12
Acetylene	6	2	.30	.04	.06	.13	13
Helium	6	0	.18	.00	.17	.12	14
Methane	6	3	.11	.08	.11	.10	15
Ozone	5	1	.21	.04	.0	.08	16
Fluorine	6	0	.18	.00	.0	.06	17
Argon	6	0	.16	.00	.0	.05	18
Nitrogen dioxide	6	4	.09	.03	.0	.04	19
Hydrogen bromide	6	5	.04	.05	.0	.03	20
Hydrogen iodide	4	3	.03	.03	.0	.02	21
Nitrogen tetroxide	6	0	.03	.00	.0	.01	24
Ethylene	4	0	.03	.00	.0	.01	24
Phosgene	3	0	.03	.00	.0	.01	24
Chloro-picrin	3	0	.03	.00	.0	.01	24
Neon	6	0	.02	.00	.0	.01	24
Cyanogen	3	0	.01	.00	.0	.003	27
Phosphine	0	0	.00	.00	.0	.00	28.5
Arsine	0	0	.00	.00	.0	.00	28.5

TABLE XII.

FREQUENCY OF OCCURRENCE OF THE PROPERTIES OF GASES IN THE SIX SELECTED TEXTBOOKS

PROPERTIES	TEXTBOOKS						Total Frequency
	A	B	C	D	E	F	
PHYSICAL							
Color	16	23	13	19	15	8	94
Odor	13	20	10	14	15	6	78
Taste	4	3	4	5	8	3	27
Weight	10	12	10	10	15	4	61
Solubility in water	10	13	14	11	16	6	70
Fumes in presence of moisture	1	1	0	1	2	0	5
Liquefaction	9	11	10	4	8	0	41
Solidification	4	8	2	1	5	2	22
Occlusion	1	0	0	0	1	0	2
CHEMICAL							
Supports combustion	5	8	7	6	10	2	38
Combustibility	7	6	5	10	13	5	46
Oxidizing Agent	1	0	2	2	2	2	9
Reducing Agent	1	1	2	3	7	1	15
Inert	1	2	1	1	4	0	9
Bleaching	2	4	2	2	5	1	16
Poisonous	4	11	4	7	7	4	37
Supports life	1	1	1	1	1	1	6

of total space in all the textbooks devoted to the topic of oxygen is 2.34, and the per cent of the total space in manuals devoted to oxygen is .62. The per cent of the total number of College Entrance Board questions devoted to oxygen is .56. The average per cent of space devoted to oxygen in the three sources is 1.17. Oxygen ranks first, according to the average per cent of space devoted to it. It is to be noted at this point that the first seven gases, with the exception of ammonia, represent the gases selected for the test. The other two gases which were chosen for the test are helium and argon, which rank 14 and 18 respectively. The reasons for the exclusion of ammonia and the inclusion of helium and argon have already been explained in this chapter. The frequency of occurrence of the properties of gases for the separate texts and manuals is shown in Tables XII and XIII. The total frequencies and ranks of these properties is shown in Table XIV. The physical properties chosen for the test during the first analysis of texts are those which rank 1, 2, 3, and 4 respectively. The chemical properties which are represented in the tests are those which rank 1, 2, and 4 in this analysis.

Table XV shows the ranking of laws and theories on the basis of average per cent of space occupied by each topic. Since the laws and theories were chosen on the criterion of their direct relationship to the mechanical fundamentals contained in the test, an agreement with the rankings of Table XV is not to be expected. The rankings for the test items selected in this case are 1, 5.5, 7, 8, 9.5, 14, and 15.

In Table XVI, the ranking of the equations is shown. The types of equations shown here which are not represented in the test are those which rank 2, 4, and 8. The reasons for excluding these types of equations have already been given.

When Table XVII is compared with Table I, it is noted that more individual types of problem are listed in Table XVII than in Table I. The type of problem involving the computation of the formula now ranks third, where before it ranked sixth. Computation of the weight of one liter occupies approximately the same rank. The percentage composition problems now hold a higher rank than the per cent problems. In the case of the textbooks, it is interesting to note the small amount

TABLE XIII.

FREQUENCY OF OCCURRENCE OF THE PROPERTIES OF GASES IN THE FIVE SELECTED MANUALS

PROPERTIES	MANUALS					Total Frequency
	A	B	C	D	E	
PHYSICAL						
Color	4	6	6	10	9	35
Odor	5	5	5	9	8	32
Taste	0	3	1	1	0	5
Weight	5	3	6	4	4	22
Solubility in water	5	6	8	7	7	33
Fumes in presence of moisture	0	1	1	1	1	4
Liquefaction	0	0	0	0	0	0
Solidification	0	0	0	0	0	0
Occlusion	0	0	0	0	0	0
CHEMICAL						
Supports Combustion	9	5	5	9	5	33
Combustibility	5	6	7	9	5	32
Oxidizing Agent	0	0	0	0	2	2
Reducing Agent	1	1	1	1	3	7
Inert	0	0	0	0	0	0
Bleaching	2	2	3	1	2	10
Poisonous	3	3	2	2	0	10
Supports life	0	0	1	1	0	2

TABLE XIV.

FREQUENCY OF OCCURRENCE AND RANK OF PROPERTIES OF GASES IN THE SIX SELECTED TEXTBOOKS AND FIVE SELECTED MANUALS

ITEM	Number of Text-books Containing the Item	Number of Manuals Containing the Item	Total Frequency in the Text-books	Total Frequency in the Manuals	Total Frequency	Rank
PHYSICAL PROPERTIES						
Color	6	5	94	35	129	1
Odor	6	5	78	32	110	2
Taste	6	5	27	5	32	6
Weight	6	5	61	22	83	4
Solubility in water	6	5	70	33	103	3
Fumes in presence of moisture	4	4	5	4	9	8
Liquefaction	5	0	41	0	41	5
Solidification	6	0	22	0	22	7
Occlusion	2	0	2	0	2	9
CHEMICAL PROPERTIES						
Supports combustion	6	5	38	33	71	2
Combustibility	6	5	46	32	78	1
Oxidizing Agent	5	1	9	2	11	6
Reducing Agent	6	5	15	7	22	5
Inert	5	0	9	0	9	7
Bleaching	6	5	16	10	26	4
Poisonous	6	4	37	10	47	3
Supports life	6	2	6	2	8	8

of space devoted to all problems ranked below "compute the weight of one liter of gas." In the case of the College Board questions, the drop in per cent occurs after the equivalent weight problems. This seems to indicate that the authors of standardized high school chemistry tests are justified in adhering to the nine ranking problems in the construction of their tests.

The analysis of the sub-types of problem is shown in Table X and is discussed in the next section.

2. *College Entrance Board Examination Analysis*

The College Entrance Board Examinations in chemistry from 1917 to 1927, inclusive, were analyzed for the purpose of checking the choice of items, the selection of which was based upon the first analysis of textbooks and the analysis of types of error made by pupils as found in previous studies. The twenty-two examinations during this period were analyzed into 1788 separate items and classified into types and sub-types. The distribution of these general types of questions is shown in Table XVIII. An inspection of this table shows the importance which the College Board examiners attach to the laboratory work, since twenty-five per cent of all their questions are on experiments. They place a strong emphasis upon equations, since 12.8 per cent of all the questions are upon the writing of equations. Gaseous elements and compounds occupy a place on equal footing with uses. From the viewpoint of these examinations, the writer is justified in his selection of the topics: principle of nomenclature, principle of valence, laws and theories, gaseous elements and compounds, equations, and numerical problems.

In the analysis of sub-topics of experiments as shown in Table XIX, the preparation of elements and compounds ranks first, with tests second, and properties third. But when it is realized that tests are an application of properties, it is easily seen that properties rank second to preparation. From the emphasis which is placed upon properties by the College Board, and from the emphasis which textbooks place upon the properties of gases as shown in Table XIV, the writer is justified in selecting the properties of gases as one of the topics to be included in his testing material.

TABLE XV.

THE RANKING OF LAWS AND THEORIES FROM THE ANALYSIS OF COLLEGE ENTRANCE BOARD EXAMINATIONS AND SIX SELECTED TEXTBOOKS

TOPIC	No. of Texts Containing The Topic	Per Cent of TotalSpace Devoted to the Topic in the Six Texts	Per Cent of Total No. of College Board Questions	* Weighted Average	Rank
Theory of Ionization	6	1.87	1.06	1.60	1
Periodic Law	6	1.07	.34	.83	2
Electron Theory	5	1.06	.00	.71	3
Atomic Theory	6	.52	.34	.47	4
Avagadro's Hypothesis	6	.40	.56	.45	5
Law of Charles	6	.49	.28	.42	6
Law of Boyle	6	.43	.34	.40	7
Kinetic Molecular Theory	5	.26	.50	.34	8
Law of Multiple Proportions	6	.14	.67	.32	9.5
Law of Mass Action	6	.48	.00	.32	9.5
Gay Lussac's Law of Volumes	6	.21	.45	.29	11
Laws of Bertholet	5	.42	.00	.28	12
Atomic numbers	5	.41	.00	.27	13
Law of Definite Proportions	6	.09	.34	.17	14.5
Law of Conservation of Matter	6	.11	.28	.17	14.5
Theory of Valence	3	.16	.00	.11	16
Law of Conservation of Energy	4	.07	.17	.10	17
Combining Weights	4	.11	.00	.07	18
Henry's Law	5	.05	.00	.03	19
Theory of Phlogiston	2	.02	.00	.01	20
Law of Octaves	2	.01	.00	.01	21
Law of Dulong and Petit	0	.00	.00	.00	22

*Textbooks are given a weight of 2 and College Entrance Board Examinations, a weight of 1.

TABLE XVI.

THE RANKING OF EQUATIONS FROM THE ANALYSIS OF COLLEGE ENTRANCE BOARD EXAMINATIONS AND SIX SELECTED TEXTBOOKS

TYPE	No. of Texts Containing The Type	Per Cent of TotalSpace Devoted to the Sub-Types in the Six Texts	Per Cent of Total No. of College Entrance Board Questions	* Weighted Average	Rank
Metathesis	6	.58	4.47	1.88	1
Oxidation and Reduction	6	.51	4.21	1.74	2
Synthesis	6	.42	1.57	.80	3
Decomposition	6	.23	.78	.41	4
Single Displacement	6	.21	.73	.38	5
Metathesis and Decomposition	6	.14	.73	.34	6
Ionic	6	.26	.34	.29	7
Word	6	.17	.00	.11	8

*Textbooks are given a weight of 2 and College Board Entrance Examinations, a weigh of 1.

The analyses of the remaining topics in the College Board examinations are shown in Tables XI, XV, XVI, XVII, and XX, which combine and compare the results of the analyses of the textbooks and College Board questions.

In Table XI, College Board has all its questions on fifteen gases among the first fifteen ranking gases of the twenty-five gases which were ranked in this analysis. It is significant to note that .17 per cent of the questions are upon the topic of helium. With the exception of argon, which is not represented in the College Board questions, every one of the gases included in the tests is represented in the College Board questions. In comparing the per cents in this table, it is interesting to note the emphasis placed upon ammonia by the College Board, while the authors of the texts and manuals stress the topics on oxygen and hydrogen.

In Table XV, which shows the rankings of the laws and theories, the agreement of College Board and authors of texts in ranking the theory of ionization first is significant. The contrast in the opinions of the two groups of individuals is very evident in the cases of the periodic law and the law of multiple proportions. The authors of the texts rank the periodic law two and the law of multiple proportions 9.5, while the College Board reverses the rank of these two laws. In Table XVI, the emphasis placed by the College Board upon equations in general is much greater than that placed upon equations by the authors, as evidenced by the consistently higher per cent of the figures for the College Board. It is interesting to note that the authors and College Board are in perfect agreement as to the ranking of each type of equation. It is significant to note the form in which these questions on equations were presented in the College Board examinations. Not a single question in the twenty-two examinations contained a question having the equation set down in completion form. In 131 of these cases, the names of the reagents were given and not their formulas. In the remaining 98 cases, the pupil was required to write the equations representing reactions in which neither the names nor the formulas of the reagents were given. In other words, only the most difficult form, the one which has been

TABLE XVII.

THE RANKING OF PROBLEMS FROM THE ANALYSIS OF THE COLLEGE ENTRANCE BOARD EXAMINATIONS AND SIX SELECTED TEXTBOOKS

TYPE	No. of Texts Containing the Type	Per Cent of Space Devoted to the Topic in the Six Texts	Per Cent of Total No. of College Board Questions	Weighted Average	Rank
Equation	6	1.83	3.30	2.32	1
Laws of Boyle and Charles	6	.86	.62	.78	2
Compute formula	5	.41	.62	.48	3
Percentage composition	6	.37	.62	.45	4
M.W. from weight of volume	5	.11	.28	.17	5
Per cent	6	.15	.00	.10	6
Compute weight of 1 liter of gas	6	.11	.06	.09	7.5
Alkalimetry and acidimetry	1	.02	.22	.09	7.5
Equivalent weight	4	.02	.17	.07	9
Find Sp. Gr. gases (to air, to hydrogen and to oxygen)	4	.07	.00	.05	11
Find valence	1	.05	.06	.05	11
Miscellany	4	.05	.06	.05	11
M. W. from atomic weight	4	.03	.06	.04	13.5
Reduction of weight to volume	6	.06	.00	.04	13.5
Combining volumes	6	.05	.00	.03	15.5
Find atomic weight	3	.04	.00	.03	15.5
M. W. from Sp. Gr. of the gas	2	.03	.00	.02	17.5
Compute number of atoms	2	.003	.06	.02	17.5
Metric	2	.02	.00	.01	22
Reduction of volume to weight	4	.02	.00	.01	22
Density of solids and liquids	3	.02	.00	.01	22
Density and pressure	1	.01	.00	.01	22
Calories	2	.02	.00	.01	22
Heat of combustion	3	.01	.00	.01	22
Ratio	2	.02	.00	.01	22
Gram-molecular weight	5	.003	.00	.002	28
M. W. from depression of freezing point	1	.003	.00	.002	28
Solubility of gases	1	.003	.00	.002	28
Carats (gold)	1	.003	.00	.002	28
Proportion	1	.003	.00	.002	28
Henry's Law	0	.00	.00	.00	31

TABLE XVIII.

FREQUENCY DISTRIBUTION OF TOPICS IN CHEMISTRY IN COLLEGE ENTRANCE BOARD EXAMINATIONS FROM 1917—1927

TYPE	No. of Questions	Per Cent of Questions
Experiments	447	25.00
Illustrations and applications	146	8.17
Composition	26	1.45
Sources	26	1.45
Uses	113	6.32
Commercial processes	70	3.92
Principle of nomenclature	86	4.81
Principle of valence	75	4.20
Laws and theories, and their applications	94	5.26
Definitions	81	4.53
Allotropic elements	28	1.57
Gaseous elements and compounds	113	6.32
Equations	229	12.80
Numerical problems	109	6.10
Miscellany	145	8.11
Total	1788	100.01

TABLE XIX.

FREQUENCY DISTRIBUTION OF SUB-TOPICS ON EXPERIMENTS IN COLLEGE ENTRANCE BOARD EXAMINATIONS

SUB-TOPIC	No. of Questions	Per Cent of Questions
Preparation	234	13.08
Properties	78	4.36
Tests (acid radicals and metals)	106	5.93
Quantitative experiments	9	.50
Miscellany	20	1.12
Total	447	24.99

called "entire equations" by the writer, was used by the College Board during the period 1917-1927.

In the ranking of problems as presented in Table XVII, the authors and College Board are in agreement upon the question of the rank of the first five types of problem. The types of problem which were selected for the tests rank 1, 2, 3, and 7.5 in the table. The percentage composition type, which has a rank of four according to this analysis, will be placed in the final form of the test. In the case of the sub-types of problem as presented in Table XX, College Board stresses the first two sub-types of problem more than do the authors of the chemistry textbooks. In the sub-types of problem involving the use of the laws of Boyle and Charles, College Board places a significant emphasis upon the law of Charles, while the authors distribute their attention rather evenly over the four sub-types of these problems.

3. Standard Minimum High School Course in Chemistry As Proposed by the American Chemical Society

Another criterion for the validity of the test is found in the "Revised Report of the Standard Minimum High School Course in Chemistry" which was proposed at the Washington meeting by the Committee of Chemical Education of the American Chemical Society in April, 1925.[32] The topics listed for such a course include those fundamentals of high school chemistry which the writer has included in his test. Thus, the laws, hypotheses, and theories proposed by this committee comprise the law of conservation of mass, law of definite proportions, the atomic theory including electrons, the law of Boyle, the law of Charles, the law of Gay Lussac, and Avagadro's hypothesis. These laws and one other not included in this list (the law of multiple proportions) are contained in the writer's diagnostic test. The following topics which are purely mechanical in nature are specified by the committee: atomic weights (not their derivation); use in performing simple chemical equations, molecular weights as explained by the law of Gay Lussac and

32 Committee of Chemical Education of the American Chemical Society. "Correlation of High School and College Chemistry." *Journal of Chemical Education.* Vol. I, 87-99. May, 1924.

TABLE XX.

THE RANKING OF SUB-TYPES OF PROBLEM FROM THE ANALYSIS OF THE COLLEGE ENTRANCE BOARD EXAMINATIONS AND SIX SELECTED TEXTBOOKS

SUB-TYPE	No. of Texts Containing Sub-Types	Per Cent of Space Devoted to the Sub-Types in the Six Texts	Per Cent of Total No. of College Entrance Board Questions	Weighted Average	Rank
Equation problems involving					
Weights	6	.98	1.17	1.04	1
Volume & weight	6	.44	1.23	.68	2
Volume	6	.21	.90	.44	3
Weights and per cent purity	6	.20	.00	.13	4
Computing atomic weight	2	.01	.00	.01	5.5
Volume, weight & per cent purity	4	.02	.00	.01	5.5
Total	6	1.83	3.30	2.31	
Percentage composition computed					
From the formula	6	.30	.56	.39	1
From the weight of constituents	5	.07	.06	.07	2
Total	6	.37	.62	.46	
Per cent problems involving					
Finding weights	6	.13	.00	.09	1
Finding volumes	1	.02	.00	.01	2
Finding per cent composition by volume	1	.003	.00	.002	4
Per cent of element in ore to be expressed as per cent of oxide	1	.003	.00	.002	4
Finding profit and loss	1	.003	.00	.002	4
Total	6	.16	.00	.11	
Formula:					
Computing simple formula	4	.21	.39	.27	1
Computing true formula	5	.20	.22	.21	2
Total	5	.41	.61	.49	

TABLE XX.—*continued*

THE RANKING OF SUB-TYPES OF PROBLEM FROM THE ANALYSIS OF THE COLLEGE ENTRANCE BOARD EXAMINATIONS AND SIX SELECTED TEXTBOOKS

SUB-TYPE	No. of Texts Containing Sub-Types	Per Cent of Space Devoted to the Sub-Types in the Six Texts	Per Cent of Total No. of College Entrance Board Questions	Weighted Average	Rank
Laws of Boyle and Charles					
Charles..	6	.17	.45	.26	1
Boyle and Charles	6	.22	.11	.18	2.5
Boyle & Charles with corrections	5	.27	.00	.18	2.5
Boyle	6	.19	.06	.15	3
Boyle and Charles—find weight	1	.01	.00	.01	4
Total	6	.86	.62	.78	
Alkalimetry and Acidimetry					
Finding concentration	1	.003	.22	.08	1
Finding weight of solute	2	.02	.00	.01	2.5
Finding normality	1	.01	.00	.01	2.5
Finding volume	0	.00	.00	.00	4
Total	2	.03	.22	.10	
Computing atomic weight					
From density and per cent composition.	2	.01	.00	.01	2
From M.W. and per cent composition..	1	.02	.00	.01	2
From per cent composition and atomic weight	1	.01	.00	.01	2
From per cent composition, M.W., and number of atoms	1	.003	.00	.002	4.5
From M.W. and atomic weight	1	.003	.00	.002	4.5
From weight of volume	0	.00	.00	.00	6.5
From specific heat and atomic weights..	0	.00	.00	.00	6.5
Total	4	.04	.00	.03	
Density of solids and liquids					
Finding density	1	.01	.00	.01	1.5
Finding weight	2	.01	.01	.01	1.5
Finding volume	0	.00	.00	.00	4
Total	3	.02	.00	.01	
Miscellaneous problems involving					
Number of molecules of water	0	.00	.06	.02	1
Use of tables	2	.01	.00	.01	2
Finding weight of solvent	1	.003	.00	.002	5.5
Weight of air over given area	1	.003	.00	.002	5.5
Addition of weights	1	.003	.00	.002	5.5
Reduction of centigrade readings to Fahrenheit	1	.003	.00	.002	5.5
Reduction of centigrade readings to absolute	1	.003	.00	.002	5.5
Finding length, shape changed, volume constant	1	.003	.00	.002	5.5
Finding cost of composite, ratios and price per ingredient given	1	.003	.00	.002	5.5
Total	4	.04	.06	.05	

Avagadro's hypothesis; symbols and formulas, their meaning and use in writing equations; valence with special reference to writing formulas; equations and their use in expressing chemical changes, including gravmetric and volumetric equations; problems involving percentage composition, weight of a substance and volumes of gases concerned in chemical relations, and the laws of gases; kinds of chemical changes such as oxidation and reduction as illustrated by direct combination, decomposition, simple replacement and double decomposition; and the writing of equations for reactions already studied. All these topics just mentioned are present in the diagnostic test. Even the five types of problem given in the test are presented in the four main types of problem which are set up by the American Chemical Society.

The topic on the theory of ionization as proposed by this Committee on Chemical Education comprises the following subtopics: explanation of the theory of electrolysis; explanation of neutralization; acid and base defined in terms of ions; test for hydrogen ions and hydroxyl ions; and atoms and ions distinguished. This topic occurs in the test both as an application and as definitions.

In the case of the eight gases whose properties the pupil is required to know in the diagnostic tests, all but two appear in this minimum course. These two gases, argon and helium, appear among the additional topics to be taught if time permits.

The validity of the topics set up by this committee is enhanced when the objectives which governed their work are considered. A quotation from their objectives will be appropriate at this point:

"1. To prepare an outline for high school chemistry which is satisfactory for students who wish to get a general knowledge of chemistry as well as for those who are going to college.

2. To list only the minimum essential topics which are common to all localities so that the high school teacher will have time in developing the course to supplement these minimum topics with material which he considers especially suitable for his locality or for the future of his students.

3. To prepare an outline which would cover the essentials of any State requirements.

4. To prepare an outline which would be in tune with the syllabus of the College Entrance Examination Board."

Since the committee's first report of "A Standard Minimum High School Course in Chemistry" had requested constructive criticism in reports published in "School Science and Mathematics" and "Industrial and Chemical Engineering", the revised report represents the results of a study of the thirty thousand criticisms which had been received by the various state committeemen. Since this report represents the careful work of eleven men qualified for this task and since the material chosen for the diagnostic tests is in accord with that of the committee's revised report, there are grounds for justification of the material selected for the tests.

4. Questionnaire Analysis

Although the fact that certain subject matter appears in textbooks, manuals, College Board Examinations, and in courses of study seems to indicate rather strongly that the material is taught in the schools, yet this fact does not prove that the subject matter is being taught. One method of getting the facts is by means of a questionnaire.

Back in 1920, the Chemistry Section of the Central Association of Science and Mathematics made a study of the fundamentals of high school chemistry by the questionnaire method.[33] The replies to 42 questionnaires show to what extent the various topics listed in the questionnaire were taught and considered as fundamentals. Listed below is that part of the data which has a direct bearing upon the items selected for the diagnostic test.

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33 Central Association of Science and Mathematics Teachers "Minutes of the Chemistry Section." *School Science and Mathematics*, 20; 242-251; March, 1920.

Concepts	Considered Fundamental	Not Stressed	Omitted
I Laws			
Charles	39	3	0
Boyle	39	3	0
Gay Lussac	39	2	1
II Theories			
Molecular	42	0	0
Atomic	42	0	0
Ionic	40	1	1
IV *Topics*			
Metric System	41	1	0
Valence	39	3	0
V *Types of Chemical Change*			
Oxidation and reduction	41	1	0
Metathesis	40	2	0

The questionnaire contained no items on the laws of definite proportions and multiple proportions, no items on numerical problems, and none on equations. Yet such topics as the metric system and the concepts of various laws may be broad enough to warrant the inference that they include problems. The use of the equations is easily inferred in the types of chemical changes which are present in the questionnaire. There are no items on the separate gases, although such a topic as "Nitrogen and Carbon Cycles" infers the inclusion of a few gaseous compounds of nitrogen and carbon.

Since this questionnaire study yields a check on part and not all types of material chosen for the diagnostic test, it is necessary to obtain a more complete and more recent survey of the field. Accordingly, a questionnaire was constructed for the purpose of determining the extent to which the topics of the diagnostic test are taught in the public schools of the United States and also to determine which high school chemistry texts and manuals are most widely used in the secondary schools.

The procedure followed in constructing and sending out this questionnaire [34] has already been described in the previous

[34] A copy of this questionnaire is contained in the appendix.

chapter. The results of the questionnaire survey of the most widely used chemistry textbooks are shown in Table XXI. This table contains the data on basic texts, basic manuals, and supplementary texts and manuals. The authors' names together with the titles of their books are arranged in the order of their frequency from the highest to the lowest in each of the three classifications. The books listed in this table are those named by eighty-three of the ninety-six city school systems which returned the questionnaires together with those which were named in the nineteen schools in which the teachers were interviewed. In all, the table contains those books which are used in 101 public school systems in the United States. An inspection of this table shows that the writer was justified in selecting for the first analysis texts and manuals by Brownlee et al., by McPherson and Henderson, by Dull, and by Gray, Sandifur, and Hanna. These results differ from those of Koos and Powers in that texts by Bradbury and by Black and Conant now occupy second and third ranks respectively in the place of McPherson and Henderson and Dull.

TABLE XXI

Frequency Distribution of Basic and Supplementary Texts and Manuals Used in 101 School Systems in the United States

Basic Texts	Frequency
1. Brownlee, Fuller, Hancock, Sohon, Whitsit: "Elementary Principles of Chemistry."	33
2. Bradbury, R. H.: "A First Book in Chemistry"	17
3. Black and Conant: "Practical Chemistry"	13
4. McPherson and Henderson: "Chemistry and Its Uses"	10
5. Dull, C. E.: "High School Chemistry"	9
6. Gray, Sandifur, and Hanna: "Fundamentals of Chemistry"	7
7. Gordon, N. E.: "Introductory Chemistry"	7
8. Bruce, G. H.: "High School Chemistry"	4
9. Greer and Bennett: "Chemistry for Boys and Girls"	4
10. Dinsmore, E. L.: "Chemistry for Secondary Schools"	4
11. Fletcher, Smith, and Harrow: "Beginning Chemistry"	4
12. Irwin, Rivett, and Tatlock: "Beginning Chemistry"	3

Basic Texts	Frequency
13. Hessler and Smith: "Essentials of Chemistry"	2
14. Newell, L. C.: "General Chemistry"	2
15. McPherson and Henderson: "Elements of Chemistry"	2
16. McPherson, Henderson, Fowler: "Chemistry for Today"	2
17. Brownlee, Fuller, Hancock, and Whitsit: "Experiments in the Chemistry of Common Things"	1
18. Holmes and Mattern: "Elements of Chemistry"	1
19. Newell, L. C.: "Practical Chemistry"	1
20.. Cook, C. G: "Practical Chemistry"	1
21. Kendall, J.: "Smith's Elementary Chemistry and Manual"	1
22. Holmes, H. N.: "General Chemistry"	1
23. Holmes and Mattern: "Elements of Chemistry"	1
24. Gordon, N. E.: "Introductory College Chemistry"	1

Basic Manuals	
1. Brownlee, Fuller, Hancock, Sohon, and Whitsit: "Laboratory Exercises"	18
2. Teachers prepare their own manuals	10
3. Bradbury, R. H.: "Laboratory Studies to Accompany 'A First Book in Chemistry'"	9
4. Gray, Sandifur, and Hanna: "Manual to Accompany 'Fundamentals of Chemistry'"	8
5. Dull, C. E.: "Laboratory Exercises in Chemistry"	6
6. McPherson and Henderson: "Course in General Chemistry: Laboratory Manual"	6
7. Black, N. H.: "Laboratory Experiments in Practical Chemistry"	5
8. Irwin, Rivett, and Tatlock: "Elementary and Applied Chemistry Manual"	2
9. Kendall, J.: "Smith's Elementary Chemistry"	2
10. Greer and Bennett: "Laboratory Manual for Chemistry"	1
11. Collister and Walbrath: "Laboratory Guide for Chemistry"	1
12. Boynton, Morse, and Watson: "Applied Chemistry Manual"	1
13. Williams and Whitman:	

Basic Manuals	Frequency
"Laboratory Exercises in General Chemistry"	1
14. Dinsmore, E. L.: "Laboratory Manual of Chemistry"	1
15. Hessler and Smith: "Laboratory Exercises"	1
16. Bruce, G. H.: "Laboratory Manual of Chemistry"	1
17. Fletcher, Smith, and Harrow: "Manual for Beginning Chemistry"	1

Supplementary Texts	Frequency
1. Brownlee, Fuller, Hancock, Sohon, Whitsit: "Elementary Principles of Chemistry"	6
2. Black and Conant: "Practical Chemistry"	5
3. Gray, Sandifur, and Hanna: "Fundamentals of Chemistry"	5
4. Bradbury, R. H.: "A First Book on Chemistry"	5
5. Gordon, N. E.: "Introductory Chemistry"	5
6. McPherson and Henderson: "General Chemistry"	4
7. McPherson, Henderson, and Fowler: "Chemistry for Today"	3
8. McPherson and Henderson: "Chemistry and Its Uses"	3
9. Dull, C. E.: "High School Chemistry"	3
10. Irwin, Rivett, and Tatlock: "Beginning Chemistry"	3
11. Holmes, H. N.: "General Chemistry"	2
12. Greer and Bennett: "Chemistry for Boys and Girls"	2
13. Bruce, G. H.: "High School Chemistry"	2
14. Holmes and Mattern: "Elements of Chemistry"	2
15. Boynton, Morse, and Watson: "Applied Chemistry Manual"	2
16. Fletcher, Smith, and Harrow: "Beginning Chemistry"	2
17. Kendall, J.: "Smith's College Chemistry"	1
18. Richardson, L. B.: "General Chemistry"	1
19. Foster, W.: "Elements of Chemistry"	1
20. Slosson, E.: "Creative Chemistry"	1
21. Bird, R. M.: "Modern Science Reader"	1
22. Findlay, A.: "Chemistry in Service of Man"	1
23. Hendrick, E.: "Every Man's Chemistry"	1
24. Jaques, A. F.: "Laboratory Chemistry for Girls"	1
25. Kahlenberg and Hart: "Chemistry"	1
26. Bailey, E. H. S.: "Sanitary and Applied Chemistry"	1

Supplementary Texts	Frequency
25. Brownlee, Fuller, Hancock, and Whitsit: "Experiments in Chemistry of Common Things"	1
28. Stannard, J. E.: "Chemistry"	1
29. Dinsmore, E. L. "Chemistry for Secondary Schools"	1
30. Fletcher, Smith, and Harrow: "Beginning Chemistry"	1
31. Howe and Turner: "Chemistry in the Home"	1
32. Emery, Davis, Downey, Boynton: "Chemistry in Every Day Life"	1
33. Kendall, J.: "Smith's Elementary Chemistry and Manual"	1
34. Smith and Mess: "Fundamentals of Modern Chemistry"	1
35. McPherson and Henderson: "First Course in Chemistry"	1
36. McFarland, B.: "Practical Elementary Chemistry"	1
37. Bradbury, R. H.: "Inductive Chemistry"	1
38. Pugh and Miller: "Problem Course in Chemistry"	1

Among the manuals, Brownlee's again ranks first and Bradbury's third. The fact that teacher's home-made manuals rank second is significant. It should be observed that the frequencies for manuals are not as high as are those for basic texts. The reason for this apparant discrepancy is that in many of the questionnaires the officials failed to name the manuals, although they named the basic texts. Although the questionnaires requested this information on manuals too, yet the officials filling out the questionnaires no doubt felt that if they did not name the manual it was understood that the manual is the one which accompanies the text. If this assumption is correct, then the assumed frequencies for the manuals should approximately equal the frequencies of the texts.

Two of the schools used no basic text at all but required their pupils to learn their chemistry from six or more high school chemistry texts and their accompanying manuals, which were kept in the library or in the science room. These teachers stated that they preferred their pupils to become familiar with several sources of information rather than depend primarily upon a single basic text.

Among the supplementary texts, Brownlee's again ranks first. Three texts, each with a frequency of five, vie for second place. Although the books in the supplementary list are primarily basic texts, yet there are a few of the reference or non-basic type. A few of the books of this type are: Slosson's "Creative Chemistry", Byrd's "Modern Science Reader", Hendrick's "Every Man's Chemistry", and Bailey's "Sanitary and Applied Chemistry."

Table XXII shows the frequency distribution of chemistry topics taught in 96 city school systems. The gas oxygen is taught both in class and by means of laboratory work in 94 of the school systems. In the teaching of carbonmonoxide, only 51 of the school systems teach this topic by means of experiments. The responses to argon and helium are interesting. The writer feels that the responses from the three schools represented in the column headed "Number Teaching Topic by Experiment" are authentic, since in the one school the name of each of the four chemistry teachers in the school is given, together with the topics which each teaches. In the second paper, helium is taught both in class and by means of experiments, while argon is not taught at all. The responses to the same items in the third questionnaire may not be valid since all the items in both columns of the first eight gases were checked.

Although the topics, argon and helium, are seldom taught by means of experiments, yet the topic of helium is taught in 77 per cent of the school systems and argon, in 67. That helium leads argon is not suprising when one considers the greater and more spectacular use of helium.

In the replies to the first eleven questions of the "yes, no" type, the per cents of "yes" answers on the questionnaire vary from 94.8 to 100 per cent. In a few cases, such as questions 15 and 18, where the totals for "yes" and "no" do not equal 96, this indicates that a few, in filling out the questionnaires, omitted these items. Four schools qualified their answers to questions 9 and 10 by stating that only a few such equations were taught.

In the replies on the types of problem taught, over 90 per cent of all the responses were in the affirmative. The problem represented in question 14 is certainly essential since 99 per cent of the responses are "yes".

TABLE XXII

FREQUENCY DISTRIBUTION OF CHEMISTRY TOPICS TAUGHT IN 96 CITY SCHOOL SYSTEMS IN 47 STATES OF THE UNION

Part I.

TOPIC	No. Teaching the Topic in Class	Number Teaching the Topic by Experiment	Per Cent Teaching the Topic in Class	Per Cent Teaching Topic by Experiment
1. Oxygen	94	94	97.9	97.9
2. Chlorine	92	90	95.8	93.7
3. Carbon monoxide	83	51	86.5	53.1
4. Argon	67	1	70.0	1.0
5. Hydrogen	94	94	97.9	97.9
6. Nitrogen	92	86	95.8	89.6
7. Carbon dioxide	94	94	97.9	97.9
8. Helium	77	2	80.3	2.1

Part II.

	Number Answering "Yes"	Number Answering "No"	Per Cent Answering "Yes"	Per Cent Answering "No"
1. Valence	96	0	100.0	0
2. Naming chemical formulas	96	0	100.0	0
3. Writing chemical formulas	96	0	100.0	0
4. Balancing chemical equations	96	0	100.0	0
5. Writing double decomposition equations	93	2	97.9	2.1
6. Writing molecular equations	96	0	100.0	0.0
7. Writing completion equations	96	0	100.0	0.0
8. Writing entire equations	95	1	99.0	1.0
9. Writing oxidation equations	91	3	94.8	3.1
10. Writing reduction equations	93	3	96.9	3.1
11. Writing ions of compounds	95	1	99.0	1.0
12. Writing ionic equations	85	11	88.5	11.5
Problems in Finding				
13. Weight of liter of gas with atomic weights given	88	8	91.7	8.3
14. Weight of reagent or product from equation	95	1	99.0	1.0
15. Volume of reagent or product when 1 volume is given	90	5	93.8	5.2
16. Volume by Charles Law	87	9	90.5	9.4

TABLE XXII.—*continued*

Part II.

FREQUENCY DISTRIBUTION OF CHEMISTRY TOPICS TAUGHT IN 96 CITY SCHOOL SYSTEMS IN 47 STATES OF THE UNION

	TOPIC	Number Answering "Yes"	Number Answering "No"	Per Cent Answering "Yes"	Per Cent Answering "No"
17.	Volume by Boyle's Law	88	8	91.7	8.3
18.	Volume by Boyle's law & Charles's law	88	7	91.7	7.
19.	Formula with percentage composition and atomic weights given	88	6	91.7	6.3
	Laws and Definitions				
20.	Law of definite proportions	95	1	99.0	1.0
21.	Law of conservation of mass	95	1	99.0	1.0
22.	Law of multiple proportions	88	7	91.7	7.3
23.	Law of Charles	86	8	89.6	8.3
24.	Law of Boyle	87	7	90.6	7.3
25.	Law of Gay Lussac (combining volumes)	91	5	94.8	5.2
26.	Definition of base (ionic)	95	1	99.0	1.0
27.	Definition for acid (ionic)	95	1	99 0	1.0

The agreement on laws and definitions is very good since over 90 per cent of the schools teach each one of these items mentioned in the list.

In the answers to the questions on laws and definitions, it is interesting to note that the per cents of "yes" responses on questions 23, 24, and 25 correspond very closely with the corresponding per cents to questions 16, 17, and 15. A follower of sound pedagogical principles would expect this result since a mastery of the laws by the pupils would not be complete without a knowledge of their applications, the applications in this case being problems. Applying this same principle again, note the agreement between the per cents of "yes" and "no" responses to questions 26 and 27 on "ions" and the per cent of responses to question 11.

Table XXIII shows the frequency distribution of topics taught by the twenty-five chemistry teachers who were interviewed by the writer. In Part II, the highest number of "no" responses is one. In Part I, carbonmonoxide is only taught as an experiment by 64 per cent of the teachers.

The official positions held by the signers of the questionnaire are shown in Table XXIV. If the frequencies for the "Head of the Science Department" and the "Head of the Chemistry Department" are added, the department heads will rank first with a frequency of 42. If the titles held by the signers of the questionnaire are any indication of the degree of responsibility assumed by them in answering the questions in the questionnaire, then their answers should be reliable.

The results of this questionnaire clearly signify that the great portion of the material selected for the diagnostic tests is taught in more than 90 per cent of the schools included in this investigation. It shows further that the two topics such as helium and argon are receiving some attention in the schools, since at least 70 per cent of the schools teach these two topics in the classroom. Since such a high per cent of teachers in this survey teach all the topics contained in the diagnostic tests, the writer concludes that from the standpoint of whether the material is taught in the schools or not, the selection of test material is valid.

TABLE XXIII.

FREQUENCY DISTRIBUTION OF CHEMISTRY TOPICS TAUGHT IN 19 HIGH SCHOOLS IN EASTERN PENNSYLVANIA AND NEW JERSEY

Part I.

TOPIC	No. Teaching the Topic in Class	Number Teaching the Topic by Experiment	Per Cent Teaching the Topic in Class	Per Cent Teaching the Topic by Experiment
1. Oxygen	25	25	100	100
2. Chlorine	25	25	100	100
3. Carbon monoxide	25	16	100	64
4. Argon	25	0	100	0
5. Hydrogen	25	25	100	100
6. Nitrogen	25	25	100	100
7. Carbon dioxide	25	25	100	100
8. Helium	25	0	100	0

Part II.

	Number Answering "Yes"	Number Answering "No"	Per Cent Answering "Yes"	Per Cent Answering "No"
1. Valence	25	0	100	0
2. Naming chemical formulas	25	0	100	0
3. Writing chemical formulas	25	0	100	0
4. Balancing chemical equations	25	0	100	0
5. Writing double decomposition equations	25	0	100	0
6. Writing molecular equations	25	0	100	0
7. Writing completion equations	25	0	100	0
8. Writing entire equations	25	0	100	0
9. Writing oxidation equations	24	1	96	4
10. Writing reduction equations	25	0	100	0
11. Writing ions of compounds	25	0	100	0
12. Writing ionic equations	25	0	100	0
Problems in Finding				
13. Weight of a liter of gas with atomic weight given	25	0	100	0
14. Weight of reagent or product from equation	25	0	100	0
15. Volume of reagent or product when 1 volume is given	24	1	96	4
16. Volume by Charles's Law	24	1	96	4
17. Volume by Boyle's Law	24	1	96	4
18. Volume by Boyle's Law & and Charles's Law	24	1	96	4

TABLE XXIII.—*continued*

Part II.

FREQUENCY DISTRIBUTION OF CHEMISTRY TOPICS TAUGHT IN 19 HIGH SCHOOLS IN EASTERN PENNSYLVANIA AND NEW JERSEY

	TOPIC	Number Answering "Yes"	Number Answering "No"	Per Cent Answering "Yes"	Per Cent Answering "No"
19.	Formula with percentage composition and and atomic weights given	25	0	100	0
	Laws and Definition				
20.	Law of definite proportions	25	0	100	0
21.	Law of conservation of mass	25	0	100	0
22	Law of multiple proportions	25	0	100	0
23.	Law of Charles	24	1	96	4
24.	Law of Boyle	24	1	96	4
25.	Law of Gay Lussac (combining volumes)	24	1	96	4
26.	Definition for base (ionic)	25	0	100	0
27.	Definition for acid (ionic)	25	0	100	0

TABLE XXIV

FREQUENCY DISTRIBUTION OF OFFICIAL POSITIONS OF THE SIGNERS OF THE QUESTIONNAIRE

Position	Frequency
1. Head of Science Department	32
2. Chemistry Instructor	30
3. Head of Chemistry Department	10
4. Superintendent of Schools	10
5. Principal of High School	4
6. Official position omitted	4
7. President of Junior College	1
8. Supervisor	1
9. Supervisor of Chemistry	1
10. Second Assistant Superintendent	1
11. Director of High Schools	1
12. Dean of the Faculty	1
	96

5. Conclusions as to Validity

Forms A and B are valid for the following reasons:

1. Both the first and second analysis of the representative high school chemistry textbooks and laboratory manuals show that all the fundamental subject matter selected for the tests is present in nearly every one of those texts and manuals which were analyzed.

2. (a) The selection of items for the test is based upon the analysis of errors made by pupils in the mechanical fundamentals of chemistry in two of the writer's previous studies.

(b) The organization of the items of the various exercises to test specific abilities which were revealed in the study of the errors committed by the pupils tends to increase the diagnostic value of the tests. This point is verified in the next chapter in which it is shown that the items are diagnostic since the great majority of errors occurs in the specific ability being tested.

3. An analysis of the College Entrance Board Examinations from 1917 to 1927 inclusive reveals the fact that these examiners deem the mechanics of chemistry and its closely related fundamentals as very important, since 44.02 per cent of their questions treat this phase of chemistry[35]. Forms A and B contain items on each type of material represented in 44.02 per cent of the College Board questions.

4. A survey of the "Revised Report of a Standard Minimum High School Course in Chemistry" as proposed by the Committee of Chemical Education of the American Chemical Society shows that the diagnostic tests are built upon certain fundamentals of the proposed high school chemistry course.

5. The questionnaire study conducted by the Chemistry Section of the Central Association of Science and Mathematics Teachers shows that part, if not all, of the fundamentals contained in the diagnostic tests is taught by the 42 teachers who answered the questionnaires.

6. This material on the mechanics of chemistry and its related fundamentals is not only contained in representative

[35] The 44.02 per cent is obtained from the data in Table XVIII by adding the per cents for the principle of nomenclature, principle of valence, law and theories and their applications, definitions, gaseous elements and compounds, equations, and numerical problems.

chemistry texts and manuals and College Board Examinations, but it is actually taught in the public schools as is shown by the results of the 96 questionnaires received from city school systems which represent every state in the Union with the exception of Nevada. Every item in the test with the exception of argon and helium are taught in 86 to 100 per cent of the 96 schools. The results of the writer's interviews of chemistry teachers in 19 school systems in and near Philadelphia are in agreement with questionnaire data.

CHAPTER III

THE DATA AND THEIR SIGNIFICANCE FOR FORMS A AND B

1. The Administration of the Tests

The general outline of procedure for the construction of these tests has already been presented in Chapter I. However, a few more details are essential at this point.

The preliminary test was constructed by the writer and tried out in his chemistry class. This trial of the test showed that the test was too long since it required 45 minutes for the class to complete it. Part I [36] on the properties of gases had required as much as 25 minutes of the time for several pupils. It was, therefore, found necessary to reduce the number of gases from nine to five and to set the list of properties within the chart rather than have them listed above.

This revised preliminary test [37] was then given in nine schools in and around Philadelphia. When the papers of the 330 pupils who had taken this test were analyzed it was realized that further revisions were necessary. Sixteen per cent of the papers showed evidence that the pupils did not have sufficient time to finish the test. In other words, the last five or more questions in the test were omitted. Part I was shortened by eliminating one gas, NO_2, which resulted in a reduction of ten items. The sample for Part I was then placed in the first column of the chart instead of above it. Since two forms were being constructed it was thought best not to have oxygen and hydrogen in the same form for the reason that both gases usually appear in the early chapters of the textbooks. If both gases remained in the same form of the test, the two forms would vary in difficulty if given during the first semester.

In Part II, questions 12 and 21 on the naming and writing of formulas were eliminated, not because the per cents of correct

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36 Part I of this preliminary test is shown in the appendix.
37 Copies of all the tests used are shown in the appendix.

TABLE XXV.

Preliminary Test—Part II.

NUMBER AND PER CENT OF PUPILS ANSWERING EACH ITEM CORRECTLY—No. OF CASES 330

No. of Questions	Number Right	Per Cent Right	No. of Question	Number Right	Per Cent Right
1	250	76.0	31	43	13.0
2	238	72.1	32	163	49.5
3	242	73.5	33	88	26.7
4	234	71.5	34	55	16.7
5	290	59.4	35	86	26.1
6	196	88.0	36	91	27.6
7	58	17.6	37	226	68.6
8	53	16.1	38	210	63.7
9	262	79.5	39	112	34.0
10	187	56.8	40	102	31.0
11	214	64.9	41	71	21.6
12	69	20.9	42	75	22.8
13	165	50.0	43	106	32.1
14	76	23.1	44	20	6.1
15	84	25.5	45	18	5.5
16	209	63.4			
17	132	40.0			
18	14	4.3			
19	122	37.0			
20	162	49.2			
21	86	26.1			
22	268	81.3			
23	248	75.2			
24	262	79.5			
25	176	53.4			
26	160	48.5			
27	127	38.6			
28	82	24.9			
29	195	59.0			
30	123	37.4			

responses were low as shown in Table XXV but because the compounds are organic compounds and general chemistry is primarily a study of inorganic chemistry. The question 7 on writing the formula for $HClO_4$ was omitted in the revised test since there was already another acid of the same series in the exercise. Question 18 on the writing of the formula for hydrosulphuric acid was omitted because one of the teachers who gave the test pointed out that H_2S is not named hydrosulphuric acid in the text he was using. A check upon six representative high school chemistry texts shows that three of them do not use this name.

A study of the errors made in writing equations revealed that the ability to write equations in molecular form should be tested separately. Accordingly, two decompositions equations, 30 and 31, were dropped from the unrevised form and two gas equations were substituted. These are questions 25 and 26 in the revised form. The types of errors for questions 29-30 of the unrevised form show the reasons for this revision.

No. of Question	Type of Error	Number of Errors
29	Balancing	5
	Valence	39
	Omissions	43
	Products	24
	Molecules	22
	Ions	2
	Total	135
30	Balancing	10
	Valence	1
	Omissions	86
	Products	88
	Molecules	20
	Ions	2
	Total	207
31	Balancing	0
	Valence	2
	Omissions	117
	Products	168
	Total	287

Not knowing the products of a reaction no doubt accounts for a large number of omissions in the answers in this part of the test. The fact that there are as high as 22 errors in writing molecular formulas shows the need of testing this operation separately.

In question 33, one hundred and sixty-seven of the errors are omissions, 72 are errors in principle, and 7 are errors in mechanics, such as addition, multiplication, etc. The omissions in this problem are likely caused by the fact that the pupils do not know how to write the equation. Since the principle element which is being tested in this problem is the principle involved in calculating the volume of gases from a gas equation and not the writing of the equation, the equation is given in this problem in the revised form. Question 39 on Gay Lussac's law of volumes has been omitted from Form A and placed in Form B. Question 41 on the writing of the equation for the reaction of quick or burnt lime on water has been omitted in the revised test.

The exercises on the writing of ionic equations were revised by omitting the last ionic equation and substituting for it two questions on expressing the compounds of electrolytes as ions. This was done in order to test this specific ability separately since the majority of the pupils who attempted the writing of the two ionic equations made errors in this principle as shown below.

No. of Question	Type of Error	Number of Errors
44.	Omissions	172
	Molecules expressed as ions	62
	Principle	72
	Formula	2
	Not finished	2
	Total	310
45.	Omissions	202
	Molecules expressed as ions	36
	Principle	66
	Mechanical	6
	Not finished	2
	Total	312

After this test had been thoroughly revised, another form of the test was constructed. These two tests, together with directions for their administration, were sent out to twelve public schools located in Pennsylvania, New Jersey, and Maryland. In the letter which accompanied the tests, teachers were asked to give one-half of their classes Form A and the other half Form B at or near the mid-year examination. During April or May, the teachers were to give the tests again, making sure that those who took Form A the first time took Form B the second time, and vice versa. The directions for giving the test were the same for every school and were followed in every case. Since the directions were uniform, any difference in results should not be due to non-uniformity of procedure.

In this second year of testing, the writer did not insist upon the various teachers scoring their papers, since he had found during his first experience, that all teachers did not follow carefully the directions given with the key. Although a few of the teachers scored their papers, the writer scored every one of the 1208 papers which were returned. During the steps of analysis which followed, any errors made by the scorer in scoring were corrected and the record of the scores changed. Before scoring was started, a key had been made out for each form. All answers were marked strictly according to keys. If, during the scoring, an answer was given which was correct but not included in the key, this new correct answer was added. Then this particular question was looked up in every test which had already been scored to see whether this correct answer had been marked wrong. If it had, this error was corrected.

In the scoring of the papers, no part credit was given for answers partially correct. In both parts of the test, the score represents the number of correct responses. The score for the test is the sum of the scores for Part I and Part II. Although Part I is of the true-false type, the number of correct responses represents the score. The formula "rights minus wrongs" was not used for two reasons. First, because the directions for Part I specifically state, "Leave a blank where you do not know the answer." Furthermore, there is concrete evidence in the test that this direction was followed by the pupils, since 299 pupils omitted 2675 questions in Part I of Form A, and 142 pupils

omitted 1633 qnestions in Part I, Form B. Second, since the test is diagnostic, whether the answer is right or wrong is of more vital importance than a computed score. Then, too, the relationship among scores is more accurately shown by the "number right" method than by the "right minus wrong" method, since there may be cases in the latter where the score which would be less than zero would be scored as zero.

2. *Distribution of Scores in Forms A and B*

After the scoring of the tests had been completed, the distribution of the scores was obtained by finding the range, quartile points, and medians of Forms A and B for each of the two testing periods and for the combination of the two periods.

The number of months which chemistry had been studied at the time of the first testing ranged from three months to six months, with the vast majority of pupils having studied chemistry five months. Of this group, twenty pupils had studied chemistry three months, while twenty-nine had studied chemistry six months. At the second testing, the length of time ranged from eight to ten months inclusive. The numbers of pupils studying chemistry eight months and nine months are approximately equal, while those representing the ten month period only number twenty pupils.

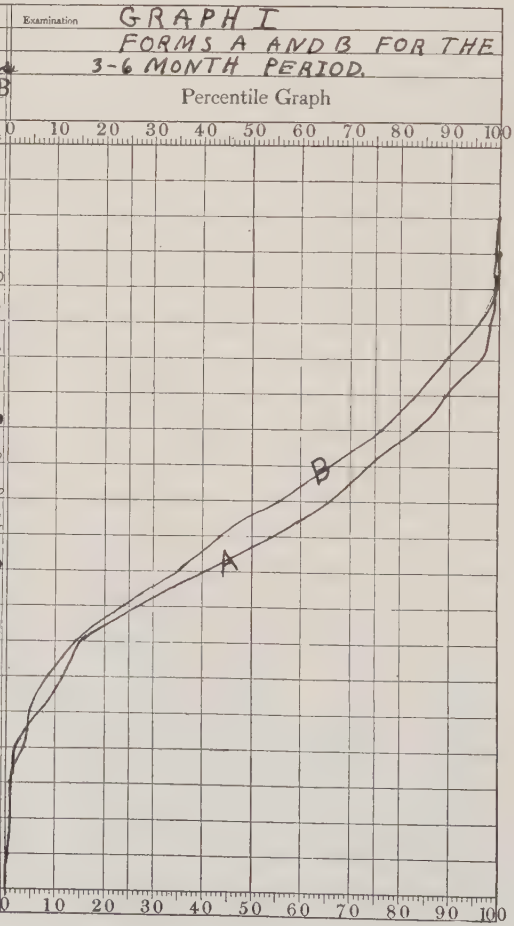
A study of the distribution of scores as shown by Table XXVI and Graphs I-V furnish the investigator with some idea of the reliability of the tests. A comparison of the A form graphs with the B form graphs shows that the curves are very similar, with only a small margin between them. In Graph II, which represents the distribution for the eight to ten month period, the margin of difference between the two curves is less than in Graph I. In fact, the two curves cross each other in the 44-47 interval. When the results of the two testing periods are combined and graphed, it is seen that there is still a greater similarity in the A and B curves and a lesser margin between the two curves. The fact that curve A and curve B are very similar during the first testing and again produce a greater similarity at the second testing is surely an indication that these tests will yield reliable results on successive testings. Had the

first testing period been of shorter duration, as was the second testing period, it is probable that there would have been a greater similarity in the A and B curves in Graph I. When the number of pupils is increased by combining the results of the two testing periods, the similarity increases—a characteristic which surely is an indication of reliability.

A study of Graphs IV and V shows not only a similarity of curves, but also a wider margin between the middle sections of the curves, due to the pupils' increasing their knowledge of chemistry between the initial and final testing. It must be

UNIVERSAL PERCENTILE GRAPH

Grade or Class							Examination	GRAPH I
Number	310			276				FORMS A AND B FOR THE
Date of Exam.	3-6 mos			3-6 mos				3-6 MONTH PERIOD.
Form Used	Form A			Form B				Percentile Graph
Score	Tallying	Sub-totals	Per cents	Tallying	Sub-totals	Per cents		
76-79		0						
72-75	2	310	100					
68-71	1	308	99+	2	276	100		
64-67	3	307	99+	10	274	99		
60-63	6	304	98+	18	264	96		
56-59	21	298	96	17	246	89		
52-55	19	277	89	20	229	83		
48-51	33	258	83	28	209	76		
44-47	23	225	73	33	181	66		
40-43	37	202	65	30	148	54		
36-39	39	165	53	27	118	43		
32-35	42	126	41	26	91	33		
28-31	37	84	27	29	65	24		
24-27	14	47	15	17	36	13		
20-23	12	33	11	8	19	8		
16-19	16	21	7	3	11	4		
12-15	3	5	2	6	8	3		
8-11	1	2	.6	1	2	.7		
4-7	1	1	.3	1	1	.3		
0-3	0	0	0					
Class Medians								



UNIVERSAL PERCENTILE GRAPH

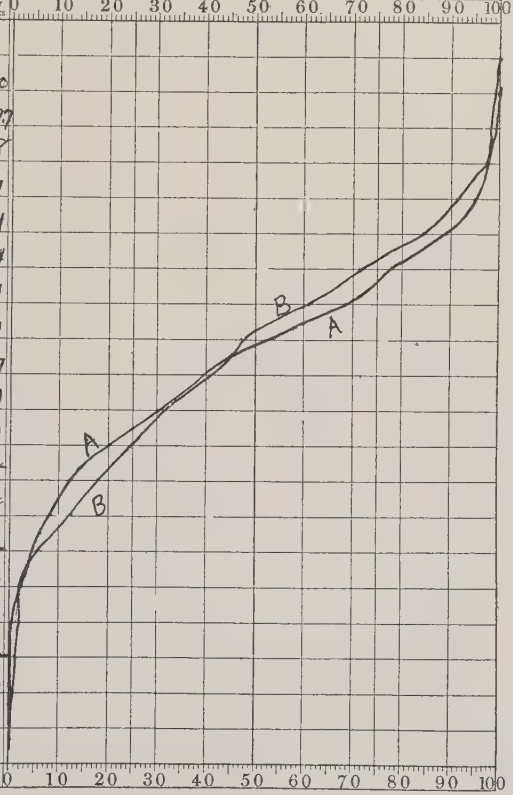
GRAPH II
FORMS A AND B FOR THE
8-10 MONTH PERIOD.

Grade or Class						
Number	314			308		
Date of Exam.	8-10 mos			8-10 mos		
Form Used	Form A			Form B		
Score	Tallying	Sub totals	Per cents	Tallying	Sub totals	Per cents
76-79				1	308	100
72-75	3	314	100	5	307	99.7
68-71	6	311	99	2	302	98
64-67	9	305	97	20	300	97
60-63	16	296	94	22	280	91
56-59	35	280	89	39	258	84
52-55	32	245	78	32	219	71
48-51	46	213	68	43	187	61
44-47	43	167	53	18	144	47
40-43	30	124	39	32	126	41
36-39	31	94	30	17	94	31
32-35	24	63	20	21	77	25
28-31	13	39	12	19	56	18
24-27	13	26	8	18	37	12
20-23	7	13	4	10	19	6
16-19	5	6	2	4	9	3
12-15	1	1	.3	3	5	2
8-11				1	2	.6
4-7				1	1	.3
0-3						
Class Medians						

Examiner

Percentile Graph

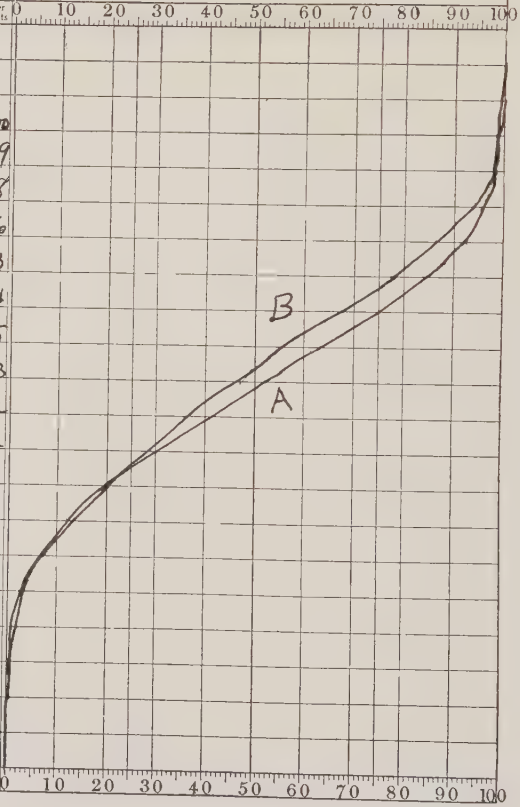
0 10 20 30 40 50 60 70 80 90 100



UNIVERSAL PERCENTILE GRAPH

Grade or Class						
Number	584			624		
Date of Exam.	3-10 Mos			3-10 Mos		
Form Used	Form B			Form A		
Score	Tallying	Sub-totals	Per cents	Tallying	Sub-totals	Per cents
76-79	1	584	100			
72-75	5	583	99	5	624	100
68-71	4	578	99	7	619	99
64-67	30	574	98	12	612	98
60-63	40	544	93	22	600	96
56-59	56	504	86	56	578	93
52-55	52	448	77	51	522	84
48-51	71	396	68	79	471	75
44-47	51	325	56	66	392	63
40-43	62	274	47	67	326	52
36-39	44	212	36	69	259	42
32-35	47	168	29	67	190	30
28-31	48	121	20	50	123	20
24-27	35	73	13	27	73	12
20-23	18	38	7	19	46	7
16-19	7	20	3	21	27	3
12-15	9	13	2	4	6	1.
8-11	2	4	.7	1	2	.3
4-7	2	2	.3	1	1	2
0-3						
Class Medians						

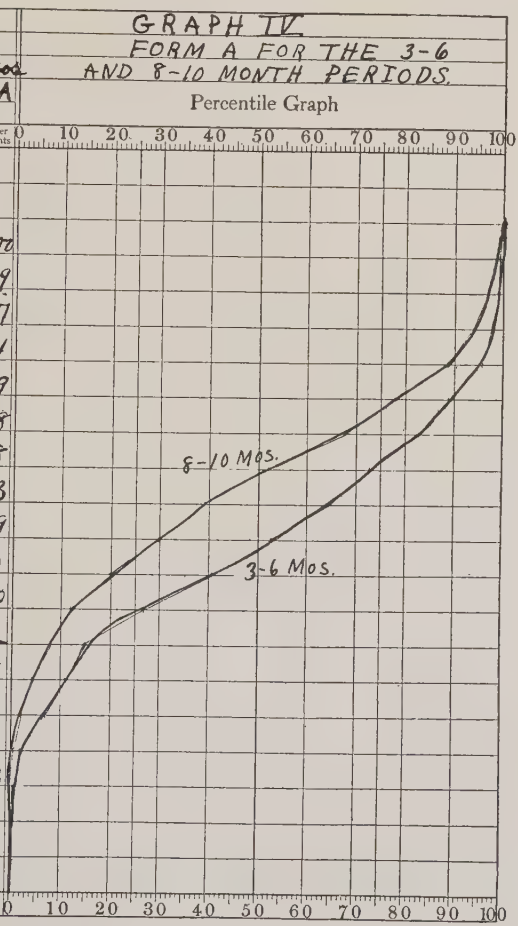
GRAPH III
FORM A AND B FOR THE 3-10 MONTH PERIOD
Percentile Graph



UNIVERSAL PERCENTILE GRAPH

GRAPH IV
FORM A FOR THE 3-6 AND 8-10 MONTH PERIODS.
Percentile Graph

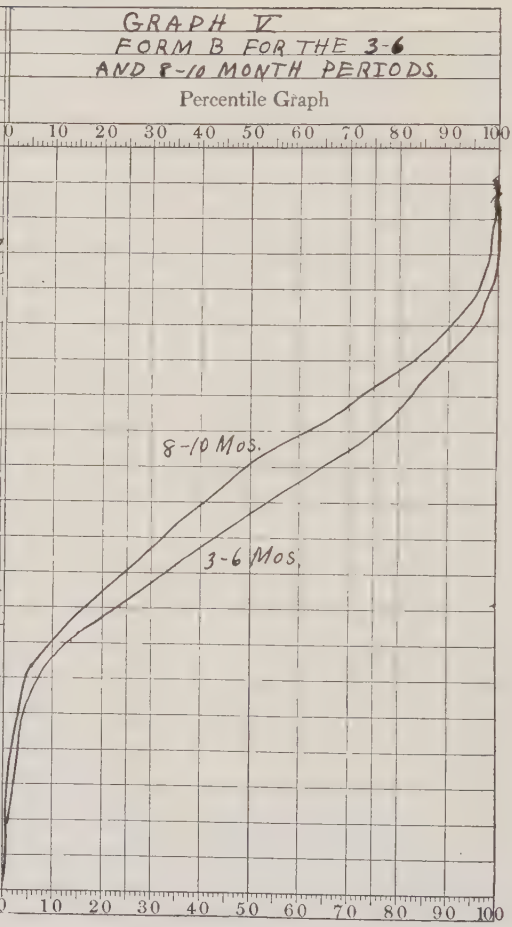
Grade or Class							
Number	310			314			
Date of Exam.	3-6 Mos			8-10 Mos			
Form Used	Form A			Form A			
Score	Tallying	Sub-totals	Per cents	Tallying	Sub-totals	Per cents	
76-79	0	0					
72-75	2	310	100	3	314	100	
68-71	1	308	99.4	6	311	99	
64-67	3	307	99.1	9	305	97	
60-63	6	304	98.1	16	296	94	
56-59	21	298	96	35	280	89	
52-55	19	277	89	32	245	78	
48-51	33	258	83	46	213	68	
44-47	23	225	73	43	167	53	
40-43	37	202	65	30	124	39	
36-39	39	165	53	31	94	30	
32-35	42	126	41	24	63	20	
28-31	37	84	27	13	39	12	
24-27	14	47	15	13	26	8	
20-23	12	33	11	7	13	4	
16-19	16	21	7	5	6	2	
12-15	3	5	2	1	1	.3	
8-11	1	2	.6	0	0	0	
4-7	1	1	.3	0	0	0	
0-3	0	0	0	0	0	0	
Class Medians							



UNIVERSAL PERCENTILE GRAPH

Grade or Class						
Number	276			308		
Date of Exam.	3-6 mos.			8-10 mos		
Form Used	Form B			Form B		
Score	Tally ing	Sub tot. ls	Per cents	Tally ing	Sub tot. ls	Per cents
76-79				1	308	100
72-75				5	307	99.7
68-71	2	276	100	2	302	98
64-67	10	274	99	20	300	97
60-63	18	264	96	22	280	91
56-59	17	246	89	39	258	84
52-55	20	229	83	32	219	71
48-51	28	209	76	43	187	61
44-47	33	181	66	18	144	47
40-43	30	148	54	32	126	41
36-39	27	118	43	17	94	31
32-35	26	91	33	21	77	25
28-31	27	65	24	19	56	18
24-27	17	36	13	18	37	12
20-23	8	19	8	10	19	6
16-19	3	11	4	4	9	3
12-15	6	8	3	3	5	2
8-11	1	2	.7	1	2	.6
4-7	1	1	.3	1	1	.3
0-3	0	0	0	0	0	0
Class Medians						

GRAPH V
FORM B FOR THE 3-6
AND 8-10 MONTH PERIODS.



remembered that curves A for the 3-6 month period and for the 8-10 month period represent the results of two different groups of pupils, since those who were tested with Form A during the first testing were tested by Form B in the second testing. The difference in curvature cannot then represent the improvement of a given group. The fact that there is a wider margin between the curves in Graph IV than there is in Graph V may be due to two factors, namely, a difference in ability between the two groups of pupils tested, or a slight difference in difficulty between the two forms of the test, or it may be a combination of both factors. However, the writer believes that the difference is in the degree of difficulty in the two forms of the test. An examination of the medians in Table XXVI shows that the medians for Form B are consistently higher than those for Form A. Thus during the 3-6 month period, the median for A is 38.75, while that for B is 41.82, and in the 8-10 month period, when the groups of pupils have been reversed, the median for A is 47.47, while that for B is 49.07. A further scrutiny of Table XXVI shows that this difference in difficulty lies in Part I of the tests, since the medians for Part I are consistently higher in Form B than they are in Form A. The specific difference in degree of difficulty can be found by reference to Tables XXXIV-XXXIX in the vertical percentages; in these it is evident that the per cents of correct responses for the ten properties of argon in Form A range from 44 to 57.4, while those for helium in Form B range from 70.2 to 71.8. The difference then in the widths of the margins between the curves in Graphs IV and V is primarily due to Form A's being less difficult than Form B.

TABLE XXVI

Total Distribution of Scores in Forms A and B

3-6 Months of Chemistry

Form A				Form B		
No. of Pupils 310				No. of Pupils 276		
	Part I	Part II	Total	B I	B II	B Total
Range	4-39	0-35	5-74	5-40	0-33	6-69
Q_3	30.21	21.04	49.29	24.30	19.75	51.86
M	26.01	13.50	38.75	29.94	13.52	41.82
Q_1	21.34	7.50	30.85	25.38	6.00	33.00

8-10 Months of Chemistry

No. of Pupils 314						No. of Pupils 308
	Part I	Part II	Total	B I	B II	B Total
Range	8-36	1-39	12-74	2-40	1-38	5-78
Q_3	32.02	25.28	55.23	34.70	25.53	56.86
M	27.96	19.38	47.47	31.40	17.62	49.07
Q_1	24.31	14.10	37.85	25.53	11.09	36.00

3-10 Months of Chemistry

No. of Pupils 624						No. of Pupils 584
	Part I	Part II	Total	B I	B II	B Total
Range	4-39	0-39	5-74	2-40	0-38	5-78
Q_3	31.00	23.42	51.84	34.32	22.05	55.00
M	27.14	16.86	42.95	30.54	16.04	45.35
Q_1	22.71	10.16	33.80	25.48	8.33	33.38

3. *The Per Cents of Correct Responses*

As has been stated previously in this dissertation, the number of correct responses to each question was recorded and the per cent of pupils answering each question correctly was computed. Tables XXVII-XXX present the data for this material for Forms A and B. Table XXVII reads as follows:

During the 3-6 month testing period in Part I, 309 of the 310 pupils answered question 1 on O_2 correctly, or 99.7 per cent of this group gave the correct response. For the same question in the 8-10 month period of testing, 310 of the 314 pupils, or 98.7 per cent of the group, answered question 1 on oxygen correctly. In the 3-10 month period, 619 of the 624 pupils, or 99.2 per cent of this group, answered question 1 on O_2 correctly. Each of the four tables is read in the same manner. The reader should take care to note that in each one of these tables the 3-6 month group of pupils is a different group from the 8-10 month group, and that the 3-10 month group represents a combination of the 3-6 and the 8-10 month groups. If the reader wishes to know the particular question referred to by each number, let him turn to the test questions in the Appendix. Thus question 1 on O_2 in Form A refers to the property of color, while question 2 on O_2 refers to the property of odor, etc.

TABLE XXVII

TOTAL NUMBER AND PER CENT OF PUPILS ANSWERING EACH QUESTION CORRECTLY IN FORM A, PART I

		3-6 Months No. of Pupils: 310		8-10 Months No. of Pupils: 314		3-10 Months No. of Pupils: 624	
No. of Ques.		No. Right	% Right	No. Right	% Right	No. Right	% Right
O_2	1.	309	99.7	310	98.7	619	99.2
	2.	307	99.0	302	96.2	609	97.6
	3.	154	49.7	160	51.0	314	50.3
	4.	272	87.7	281	89.5	553	88.6
	5.	182	58.7	177	56 4	379	60.8
	6.	285	91.9	296	94.3	581	93.1
	7.	168	54.2	195	62.1	363	58.2
	8.	273	88.0	275	87.6	548	87.8
	9.	252	81.3	249	79.3	501	80.3
	10.	249	80.3	286	91.1	535	85.8
Cl_2	1.	259	83.6	245	78.0	504	80.8
	2.	278	89.7	290	92.4	568	91.1
	3.	255	82.3	262	83.4	517	82.9
	4.	296	95.5	300	95.6	596	95.5
	5.	255	82.3	258	82.2	513	82.2
	6.	141	45.5	94	29.9	235	37.7
	7.	193	62 3	223	71.0	416	66.7
	8.	125	40.3	112	35.7	237	38.0
	9.	184	59.4	161	51.3	309	49.5
	10.	269	86.8	299	95.2	568	91.1
CO	1.	231	74.5	240	76.4	471	75.5
	2.	158	51.0	201	64.0	359	57.5
	3.	92	29.7	123	39.2	215	34.5
	4.	255	82.3	267	85.0	522	83.7
	5.	70	22 6	104	33.1	174	27.9
	6.	199	64.2	202	64.3	401	64.3
	7.	131	42.3	143	45.5	274	43.9
	8.	186	60.0	179	57.0	365	58.5
	9.	192	61.9	197	62.7	389	62.4
	10.	230	74.2	263	83.8	493	73.0
A	1.	161	51.9	207	65.9	368	59.0
	2.	146	47.1	189	61.2	335	53.7
	3.	106	34 2	131	41.7	237	38.0
	4.	173	55.8	217	69.1	390	62.5
	5.	115	37.1	153	48.7	268	43.0
	6.	141	45.5	187	59.6	328	52.6
	7.	135	43 6	180	57.3	315	50.5
	8.	107	34.5	153	48.7	260	41.7
	9.	121	39.0	177	56.4	298	47.8
	10.	157	50.6	210	66.9	367	58.8

Table XXVII shows us that questions which are difficult the first time are usually difficult the second time. It shows that the same holds true for the easier questions. Thus under "oxygen," item 7 on "Burns in air" proves to be difficult for both groups of pupils. This difficulty is due to a confusion of the term "burns" with the term "supports combustion," as is shown a little later in this chapter under the study of combination of errors. Under chlorine, item 4 seems to be the least difficult. This item is the "Same weight as air." This is the easiest item in the three of the four gases. One would think that it should be the easiest item for oxygen, but it is not. This item should have proven the least difficult for all four of the gases, since not a single gas in Forms A and B has the same weight as air. Yet, in Table XXIX for Form B, item 4 is the least difficult for only two of the gases, CO_2 and He. Probably this can be explained by the pupils' having more intimate laboratory experiences with some of these gases than with others. Thus none of the pupils in these groups has had laboratory or demonstration experiments on argon and helium. Their answers as to the weight of these gases can be obtained by reasoning from the data on atomic weights, which is given under the directions in Part 1. Then, too, laboratory experiences as to color of gases in the laboratory have no doubt been more lasting than the experiences concerning the weights of the gases.

The greater increase of correct responses appears in the ten questions under argon. Why are there not the same increases for the items under each of the other gases? The reason for this discrepancy is that the rare gases, such as helium and argon, are not studied in many of the schools until the second semester. The factor of forgetting may account for the slight falling off of per cents correct during the second testing period. But again the reader must be slow in drawing such a conclusion, because the same group of pupils is not compared in Table XXVII. The per cents for all ten items under argon are lower than for any other gases in Form A. It must be noted, however, that any information which the pupil has obtained he has obtained by reading and from the data given on the gas at the top of the test sheet.

The per cents for oxygen in items 6, 7, and 8 are interesting since the properties are closely associated. Thus item 8, "A lighted stick thrust into it goes out," is the experimental proof for item 6, "supports combustion." The per cents for item 6 are higher for both groups than they are for item 8. One would think that the reverse should be true, since we are led to believe that laboratory experience would make a more lasting impression than classroom experience. The same relationship of per cents occurs in items 6 and 8 under CO, but here the result is not so surprising, since experiments on CO are usually demonstrations and not laboratory experiments. Quite frequently no experiments are performed in the case of this gas.

Item 6, under chlorine in the 8-10 month group, is rather significant. Why should those who have studied chemistry longer fail to such a marked degree on this item? This group has failed nearly as badly on the experimental phase of this property as shown in item 8. Here, however, the laboratory experience has been remembered by a greater proportion of the pupils than has the classroom experience. This contrast between the results of the two groups of pupils may have been caused by the fact that chlorine was taught during the first semester, and the factor of forgetting has played a greater part in remembering the properties of chlorine, which is not as familiar a gas to the pupils as is oxygen or hydrogen.

When the per cents for argon are compared with those of helium it is noted that helium receives much higher per cents of correct responses than does argon. This is not surprising, since texts devote more space to the uses of helium than they do to those of argon. The pupils have no doubt seen dirigibles and read accounts of them in the newspapers, and therefore know more about them than they do about argon.

In table XXVIII, which is read in the same manner as Table XXVII, the reader notes that item 5 of the first five questions on the principle of valence is the most difficult. This result is to be expected, since item 5 represents the application of the principle in a new situation. Of the other four questions, number 3 is the most difficult, since it requires two subscripts instead of one.

TABLE XXVIII

TOTAL NUMBER AND PER CENT OF PUPILS ANSWERING EACH QUESTION CORRECTLY IN FORM A, PART II

	3-6 Months No. of Pupils: 310		8-10 Months No. of Pupils: 314		3-10 Months No. of Pupils: 624	
No. of Ques.	No. Right	% Right	No. Right	% Right	No. Right	% Right
1.	200	64.5	267	85.0	467	74.9
2.	168	54.2	241	76.8	409	65.6
3.	165	53.2	236	75.2	401	64.3
4.	207	66.8	243	77.4	450	72.1
5.	134	44.2	199	63 4	333	53.4
6.	274	88.4	302	96.2	576	92.3
7.	204	65.8	280	89.2	484	77.6
8.	152	49.0	210	66.9	362	58.0
9.	110	35.5	157	50.0	267	42.8
10.	67	21.6	144	45.9	211	33 8
11.	20	6.5	32	10.2	52	8.3
12.	133	42.9	205	65.3	338	54.2
13.	68	21.9	99	31.5	167	26.8
14.	75	24.2	111	35.4	186	29.8
15.	31	10.0	61	19.4	92	14.7
16.	113	36.5	142	45.2	255	40.9
17.	33	10.6	72	22.9	105	16.8
18.	226	72.9	255	81.2	481	77.1
19.	214	69.0	251	79.9	465	74.5
20.	216	69.7	245	78.0	461	73.9
21.	68	21.9	99	31 5	167	26.8
22.	64	20.6	93	29 6	157	25.2
23.	75	24.2	114	36.3	189	30.3
24.	49	15.8	48	15.3	97	15.5
25.	104	33.6	148	47.1	252	40.4
26.	101	32.6	106	33.8	207	33.2
27.	115	37.0	153	48.7	268	43.0
28.	89	28.7	142	45.2	231	37.0
29.	60	19.4	107	34 1	167	26.8
30.	29	9.4	38	12.1	67	10.7
31.	70	22.6	114	36.3	184	29.5
32.	26	8.4	47	15.0	73	11.7
33.	1	.3	13	4.1	14	2.2
34.	225	72.6	233	74.2	458	73.4
35.	146	47.1	195	62.1	341	54.7
36.	89	28.7	89	28.3	178	28.5
37.	73	23.5	98	31 2	171	27.4
38.	39	12.6	108	34.4	147	23.6
39.	64	20.6	117	37.3	181	29.0
40.	20	6.5	71	22 6	91	14.6

In the next group of questions (6-11) on nomenclature, number 11 (NaClO) proves to be the most difficult to name. It is true that the pupil has little acquaintance with this compound, but he has been taught the principle of naming compounds, and in this case is given the fundamental formula and its name in the sample of series of compounds to which NaClO belongs. One is led to infer from the results in this group and the following group of questions on formulas that the pupil depends more upon his memory for naming and writing formulas than he does upon the application of a principle. This inference is borne out by the fact that the pupil is more familiar with the other compounds in this group of questions and has, therefore, answered a higher proportion of them correctly. The pupils have done this in spite of the fact that, if reasoning is used, two operations instead of one are required. The pupil must, first of all, know the formula and the name of the fundamental compound, and he must know the principle of naming the formula. Since these pupils did not apply the knowledge of the principle when the fundamental formula was given, the writer is led to believe that they did not apply the principle to the other cases in the group, but preferred to depend solely upon memory.

In the next group of questions (12-17) on writing formulas, questions 15 and 17 proved to be the most difficult. Number 17 was difficult for the reason that the naming of NaClO was the most difficult in the preceding group. Number 15 proved to be difficult for two or more reasons. The two principal reasons are concerned with the pupils' knowing the valence of the CO_3 radical and their knowing the formula for the ammonium radical. These are discussed later under the types of error.

Of all the questions on equations, the group on balancing equations (18-20) proved to be the least difficult, since this group represents the first and simplest step in the writing of equations. The per cents for the second testing period are higher than for the first. They also show that item 20 is the most difficult, since the balancing of this equation requires the computing and placing of four coefficients instead of one or two, as required in equations 19 and 18.

The operation of completing double decomposition equations (21-22) proved to be more difficult than writing and balancing molecular equations (25-26), in spite of the fact that the directions and the sample indicated just how such an equation is to be written, while no directions or samples were given to aid the pupil in writing molecular equations. It is true that two operations, the writing of formulas and the balancing of equations, are involved in writing double decomposition equations, but two operations are also involved in writing the molecular equations in 25 and 26: the principle of writing molecules and the balancing of the equation. The reason for the molecular equations being the less difficult is that the pupils are more familiar with the reactions represented there than they are with those in questions 21 and 22. Again, memory in preference to reasoning plays the predominant part in the case of those pupils who succeeded in molecular equations but failed in the double decomposition equations.

In the four remaining questions on equations (27, 28, 39, 40) the questions in which the complete response was required possessed the greatest degree of difficulty as shown by the lower per cents in questions 39 and 40.

For the questions on problems (23, 24, 29, 30, 38), it is evident that all the per cents of correct answers are low, in fact, all are below 50 per cent. This verifies the findings made by S. R. Powers of Columbia,[38] in his study. Question 30 on Charles's law possesses the greatest degree of difficulty. Question 23 yielded the highest per cent of correct responses, in spite of the fact that it requires the greatest number of operations and the greatest amount of calculation of all five problems. However, not only should this type of problem yield the highest per cent of correct responses of all five problems, but should have received a very high per cent as well for the reason that this represents the most important type of problems, as shown by the analysis of texts and College Board questions.

The questions on ions (31-33) were indeed very difficult for the pupils. This topic, although taught and deemed essential, evidently is not stressed or is poorly taught. This poor

38 Powers, S. R.: "A Diagnostic Study of Subject Matter of High School Chemistry." *Columbia Univtrsity Contributions to Education.* 149, 1924, p. 19.

showing for the theory of ionization appears again in Question 35.

The results of the multiple choice questions on laws and theories (34-37) also proved rather disappointing, since two of the per cents are below 50 per cent, while the other two are not very high. Question 34, an illustration of the law of definite proportions, was the easiest question for the group, while the illustration of the law of conservation of matter, 37, was the most difficult.

Table XXIX presents the data of Form B on Part I, and in the main its results follow very closely those of Form A in Part I. Thus the per cents representing degrees of difficulty for items 6, 7, and 8 follow the same order of difficulty as they do in these items under oxygen in Form A. This order of difficulty is consistent for all four gases in Form B, while in Form A, this order was not consistent throughout. Part I in Form B is less difficult than Part I in Form A, since argon in Form A consistently has lower per cents of correct responses than does helium in Form B.

The data presented in Table XXX corresponds very closely to those given in Table XXVIII. In the first group of questions on valence, question 3 has received a higher per cent than it deserves ,since $AlPO_4$ is correct as it stands, and it is not possible to determine whether it was omitted by the pupil or thought to be correct as it stands. However, by making a study of these questions in the pupils' papers it is possible to determine whether the pupil omitted the question or thought it was correct. If the pupil has omitted other questions in this group of five questions, one can feel almost certain that he omitted $AlPO_4$. By counting question 3 as wrong when others in the group have been omitted, it was found that there were thirty-nine omissions for question 3. This gives for the revised per cent in the 3-10 month period 6.7 per cent for omissions. The complete data on this point are given as follows:

	3-6 Months	8-10 Months	3-10 Months
No. of omissions	28	11	39
Per cent of omissions	10.2	3.6	6.7

TABLE XXIX

TOTAL NUMBER AND PER CENT OF PUPILS ANSWERING EACH QUESTION CORRECTLY IN FORM B, PART I

		3-6 Months No. of Pupils: 276		8-10 Months No. of Pupils: 308		3-10 Months No. of Pupils: 584	
No. of Ques.		No. Right	% Right	No. Right	% Right	No. Right	% Right
H_2	1.	273	98.9	306	99.4	579	99.1
	2.	263	95.3	294	95.5	557	95.4
	3.	246	89.0	286	92.9	532	91.1
	4.	274	99.3	295	95.8	569	97.4
	5.	245	88 9	279	90.6	524	89.7
	6.	155	56.2	134	43.5	289	59.5
	7.	216	78.3	231	75.0	447	76.5
	8.	136	49.3	121	39.3	257	44.0
	9.	198	71.7	220	71.4	418	71.6
	10.	206	74.6	256	83.1	462	79.1
N_2	1.	235	85.1	267	86.7	502	86.0
	2.	209	75.7	232	75.3	441	75.5
	3.	128	46.4	153	49.7	281	48.1
	4.	239	86.6	262	85.1	501	85.8
	5.	113	40.9	139	45.1	252	43.1
	6.	169	61.2	193	62.7	362	62.0
	7.	180	65 2	176	57.1	356	61.0
	8.	155	56.2	162	52.6	317	54.3
	9.	168	60.9	207	67.2	375	64.2
	10.	185	67.0	244	79.2	429	73.5
CO_2	1.	198	71.7	256	83.1	454	77.7
	2.	149	54 0	201	65.3	350	59.9
	3.	222	80.4	239	77.6	461	78.9
	4.	245	88.9	277	89.9	522	89.4
	5.	230	83.3	250	81.2	480	82.2
	6.	200	72 5	224	72.7	424	72.6
	7.	190	68.8	212	68.8	402	68.8
	8.	193	69.9	220	71.4	413	70.7
	9.	177	64.1	180	58.4	357	61.1
	10.	185	67 0	225	73.1	410	70 2
He	1.	211	76.4	257	83.4	468	80.1
	2.	193	69.9	225	73.1	418	71.6
	3.	226	81.9	236	76.6	462	79.1
	4.	247	89 5	266	84.4	513	87.8
	5.	219	79.3	234	76.0	453	77.6
	6.	191	69.2	214	69.5	405	69.3
	7.	167	60.5	208	67.5	375	64.2
	8.	129	46.7	164	53.3	293	50.2
	9.	157	56.9	178	57.8	335	57.4
	10.	202	73.2	229	74.4	431	73.8

TABLE XXX

TOTAL NUMBER AND PER CENT OF PUPILS ANSWERING EACH QUESTION CORRECTLY IN FORM B, PART II

	3-6 Months No. of Pupils: 276		8-10 Months No. of Pupils: 308		3-10 Months No. of Pupils: 584	
No. of Ques.	No. Right	% Right	No. Right	% Right	No. Right	% Right
1.	192	69.6	243	78.9	435	74.5
2.	129	46.7	205	66.5	334	57.2
3.	192	69.6	227	73.7	419	71.7
4.	105	38.0	141	45.8	246	42.1
5.	98	35.5	153	49.7	251	43.0
6.	140	50.7	213	69.2	353	60.4
7.	147	53 3	195	63.3	344	58.9
8.	28	10.1	34	11.0	62	10.6
9.	95	34.4	136	44.2	231	39.6
10.	114	41.3	165	53.6	279	47 8
11.	11	4.0	15	4.9	26	4.5
12.	140	50.7	230	74.7	370	63.4
13.	59	21.4	63	20.5	122	20 9
14.	70	25.4	94	30.5	164	28.1
15.	86	31.2	132	42.9	218	37.3
16.	46	16.7	68	22.1	114	19 5
17.	8	2.9	28	9.1	36	6.2
18.	192	69.6	237	77.0	429	73.5
19.	167	60.5	224	72.7	391	67.0
20.	154	55.8	208	67.5	362	62.0
21.	151	54.7	209	67.9	360	61.6
22.	57	20.7	89	28.9	146	25 0
23.	74	26.8	98	31.8	172	29.5
24.	36	13.0	61	19.8	97	16.6
25.	91	33.0	130	42.2	221	37 8
26.	101	36.6	149	48.4	250	42.8
27.	167	60.5	210	68.2	377	64.6
28.	77	27.9	151	49.0	228	39.0
29.	39	14.1	92	29.9	131	22.4
30.	48	17.4	65	21.1	113	19.3
31.	82	29.7	128	41.6	210	36.2
32.	23	8.3	28	9.1	51	8.7
33.	2	.7	9	2.9	11	1.9
34.	128	46.4	188	61.0	316	54.1
35.	118	42.8	133	43.2	251	43.0
36.	108	39.1	128	41.6	236	40.4
37.	70	25.4	85	27.6	155	26.5
38.	41	14.9	81	26.3	122	20.9
39.	42	15.2	84	27.3	126	21.6
40.	19	6.9	73	23.7	92	15.8

Of the thirty-nine omissions, twenty-five, or 64.1 per cent were committed by pupils of one large city school which ranks twelfth among the twelve schools tested.

This weakness in question 3 will be removed in the final tests by having the pupils write the formulas in provided blanks, rather than have them supply subscripts as they did in the present tests. This question was placed in Form X in the revised form, and was tried on 162 pupils, with the result that 79 per cent of the pupils answered the item correctly. Since Form X was given near the close of the term, this 79 per cent item should be compared with the 73.7 per cent item under the 8-10 month heading. The difference is not so great as to affect appreciably the results of the test in future trials.

In questions 6-11 on nomenclature, number 11 proves to be the most difficult item for the same reason that it was in Form A. Item 10 on an acid salt proved less difficult in Form B than in Form A because $NaHCO_3$ (baking soda) is no doubt a more familiar compound to the pupil than is $KHSO_4$, although the principle of nomenclature is identical in both cases.

In the writing of formulas, question 17 (potassium dichromate) was answered by only 6.2 per cent of the 584 pupils. This compound is usually taught near the close of the course, and it may be possible that not many of the pupils had studied the properties and uses of the compound in the text or performed experiments involving its use. The principal difficulty with number 15 (ferrous hydroxide) is its valence.

The questions, 18-20, on the balancing of equations in Form B seem to be more difficult than those in Form A, although the number of coefficients to be computed is the same in both tests. Question 27 in Form B ($Zn + H_2SO_4$) was answered correctly by 64.6 per cent of the pupils, while ($Zn + HCl$) in Form A was answered correctly by 43 per cent of the pupils. One would hardly expect such a great difference in correct responses between two equations which are nearly alike. This difference can be accounted for on the grounds that H_2SO_4 rather than HCl is usually used in the making of hydrogen and that the H_2SO_4 equation appears far more frequently in the texts than the HCl equation. A comparison of the per cents for 28 and 40 is interesting, since the

equation is the same in both questions. Question 40 is the more difficult of the two, since the pupil has to be able to write the formulas for the reagents as well as complete the same other operations which are required in number 28.

In the questions on problems (23, 24, 29, 30, 38), all the per cents of correct responses are again less than 50 per cent. The most difficult problem this time was number 24 on finding the weight of a liter of gas. Question 23, the most important type of problem again ranked first in the number of pupils making correct responses.

The results of questions 31-33 on ionization correspond very closely to the results for Form A.

In the questions 34-37 on laws and theories, question 34 on ionization, unlike a similar question in Form A, ranked first in the per cent of correct responses; yet the per cent of correct responses, 54.1, in Form B, nearly equals 54.7 per cent for the same question in Form A. Question 37 on Gay Lussac's law proved to be the most difficult item in this group.

A bird's-eye view of the data presented in the tables just discussed is shown in Tables XXXI-XXXIII. Table XXXI indicates for Part I of Forms A and B the average per cent of correct responses for the 3-6, 8-10, and 3-10 month testing periods. The average per cents of correct responses for Part I of Form A are consistently lower than those for Part I in Form B. As has already been stated, Form A is the more difficult on account of greater difficulty of the ten items on argon. The difference in achievement between the results of the two testing periods does not really indicate improvement, since the two groups whose achievements are measured are not the same groups. The same caution must be borne in mind in the study of Tables XXXII and XXXIII, which contain a similar item on improvement.

In Tables XXXII and XXXIII, the results of Tables XXVIII and XXX have been condensed according to topics, and their per cents averaged. Table XXXII reads as follows: In the topic of valence, questions 1-5, the average per cent of correct responses was 56.4 for the 3-6 month group, 75.5 per cent for the 8-10 month group, thus yielding a difference or an im-

provement of 19.1 per cent, and an average of 66 per cent for the 3-10 month period. A study of this table reveals the fact that the principle of valence was the easiest topic in Part II, but that at the same time the greatest difference in achievement between the two testing periods occurred in valence. Balancing of equations, at 75.2 per cent, surpasses valence, but it is a sub-topic under equations. The next greatest improvement took place in nomenclature and the writing of formulas. In equations, the greatest improvement occurred in completion equations and in entire equations. The least improvement was shown in the laws. This analysis shows that the naming of formulas is easier than the writing of formulas. The same is true in Form A. These findings do not support the findings of S. R. Powers and Julia S. Bennett in their investigations with Powers Chemistry tests. It has been the writer's experience in the case of the Powers test that the slower pupils seldom have time to finish all the test, and therefore do not have an opportunity to answer any or all of the questions in Part II on formula naming. This, then, may account for the findings of Powers, Bennett,[39] and Malin[40] when the Powers tests were used. Since there were more questions both in the naming and in the writing of formulas than there were in the Powers test, and since the pupils had ample time in which to try all twelve questions, the writer feels that his evidence is more significant than that of Dr. S. R. Powers and that of Julia S. Bennett. Furthermore, the questions for the writer's tests were selected specifically to perform a diagnostic function, while those in the Powers tests were selected for achievement purposes.

This table shows that the topic of ionization is least understood by the pupils and that problems rank next to ionization in this respect.

What has been said concerning the topics in Table XXXII can be said for Table XXXIII, which contains similar data on Form B. The topics rank approximately in the same order of difficulty in Form B that they do in Form A.

39 Bennett, Julia: "A Study of Pupil Errors in Chemistry." *Journal of Educational Research*, XIV, pp. 275-283, Nov., 1926.

40 Malin, J. E.: "A Diagnostic Study of Students' Difficulties in Chemistry and the Effects of Application of Remedial Measures." Master's Thesis, 1927.

TABLE XXXI

Summary of Tables XXVII and XXIX

	Form A, Part 1 Per cent Right	Form B, Part 1 Per cent Right
3-6 Months	62.9	71.7
8-10 Months	67.6	72.8
Improvment	4.7	1.1
3-10 Months	65.3	72.3

TABLE XXXII

Condensed Table for Part II, Form A

	3-6 mos. Per cent Right	8-10 mos. Per cent Right	Improv. Per cent Imp.	3-10 mos. Per cent Right
Valence (1-5)	56.4	75.5	19.1	66.0
Nomenclature (6-11)	44.5	59.7	15.2	52.1
Formulas (12-17)	24.4	36.6	12.2	30.5
Bal. Eqs. 18-20	70.1	79.7	9.6	75.2
Ex. Eqs. 21, 22	21.3	30.6	9.3	26.0
Mol. Eqs. 25, 26	33.1	40.4	7.3	36.7
Comp. Eqs. 27, 28	32.9	46.9	14.0	40.0
Entire Eqs. 39, 40	13.5	29.9	16.4	21.8
All Eqs.	37.5	48.6	11.1	43.1
Problems 23, 24, 29, 30, 38	16.3	26.4	10.1	21.4
Ions 31-32	15.5	25.6	10.1	20.6
Ionic Eq. 33	.3	4.1	3.8	2.2
All Ions 31-33	10.4	18.5	8.1	14.5
Laws 34-37	43.0	49.0	6.0	46.0

TABLE XXXIII

Condensed Table for Part II, Form B

	3-6 mos. Per cent Right	8-10 mos. Per cent Right	Improv. Per cent Imp.	3-10 mos. Per cent Right
Valence (1-5)	51.9	62.9	11.0	57.7
Nomenclature (6-11)	32.3	41.0	8.7	37.0
Formulas (12-17)	24.7	33.2	8.5	29.2
Bal. Eqs. (18-20)	62.0	72.4	10.4	67.5
Ex. Eqs. (21-22)	37.7	48.5	10.8	43.3
Mol. Eqs. (25, 26)	34.8	45.3	10.5	40.3
Comp. Eqs. 27, 28	44.2	58.6	14.4	51.8
Entire Eqs. 39, 40	11.1	25.5	14.4	18.7
All Eqs.	40.1	52.1	12.0	46.4
Problems 23, 24, 29, 30, 38	17.2	25.8	8.6	21.7
Ions 31, 32	19.0	25.3	6.3	22.3
Ionic Eq. 33	.7	2.9	2.1	1.9
All Ions 31-33	12.9	17.8	4.9	15.5
Laws 34-37	38.4	43.3	4.9	41.0

4. *An Analysis of Part I in Both Tests*

The next step in the investigation consisted in the analysis of Part I of Forms A and B from another angle. The results of this analysis appear in Tables XXXIV-XXXIX. All these tables are set up in the same manner and all are read and interpreted in the same way. Before explaining how these tables are read and interpreted it will be worth while to see how they were constructed. If the set up of Forms A and B is examined, the reader will understand what is meant in the "Directions for Scoring" [41] when it says: "At the right of the last space of each horizontal line set down the number of correct responses. Score the vertical column in the same manner and place the score at the foot of each column. If the counting of scores has been correct the sum of the vertical scores will equal the sum of the

[41] See Forms A and B and "Directions for Scoring" in the Appendix.

horizontal scores." If the pupil has made no errors in Part I, each horizontal line will score 4, while each vertical column will score 10. The totals in both cases will be 40. The writer was interested in knowing to what extent pupils made scores of 4, 3, 2, 1, and 0 in each of the horizontal items, and to what extent pupils made scores of 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, and 0 in the vertical columns. The number of pupils making each of the aforementioned horizontal and vertical scores was then determined. The per cent of pupils making each score was then computed. The per cent of correct responses for each series of horizontal or vertical scores were calculated by multiplying each score by the number of pupils making that score and then adding these products and dividing by the products of the perfect score and the total number of pupils.

Table XXXIV is read as follows: In question 1 on the four gases for the 3-6 month testing period, 119 pupils made a perfect score in giving the correct responses for all four gases, said number of pupils constituting 38.4 per cent of the 310 pupil group; 106 pupils, or 32.2 per cent of the same group made a score of 3; 76 pupils, or 24.5 per cent of the group made a score of 2; 8 pupils, or 2.6 per cent of the pupils made a score of 1; and 1 pupil, or .3 per cent of the pupils made a score of zero. The total number of correct responses (954) to the four items in question 1 was 76.9 per cent of a possible perfect score of 1240, (4 x 310). The data on the following questions are read in the same manner. The totals at the bottom of the columns are read in the following manner: For all ten questions 623 responses or 20.1 per cent of the responses represent a perfect score of 4 in all ten questions. ($623 \div [10 \times 310] = 20.1\%$); 1014, or 32.7 per cent of the responses were three's, etc. There was a grand total of 7797 correct responses, which represent 62.9 per cent of the total number of possible correct responses. ($7797 \div [4 \times 310] = 62.9\%$).

The second part of Table XXXIV reads as follows: 57 pupils, or 18.4 per cent of them, made a perfect score of 10 in the vertical column on oxygen; 57 pupils, or 18.4 per cent of the group, made a score of 9 on oxygen, etc. In all, for oxygen there were 2448 correct responses, which represent 79 per cent of all responses. The numbers and per cents for the totals col-

umns are read in the same manner as they are read for the horizontal columns.

Note in these tables that there is a constant check on accuracy, since the sum of the per cents in the horizontal rows must always equal 100 per cent, and since the sum of the totals in the extreme right hand column must always check with the sum of the totals along the bottom row in each case. Then, too, the grand total for the horizontal responses must always equal the grand total for the vertical responses.

It is interesting to note in all these tables that the per cents of perfect scores, both in the horizontal and vertical per cents are low. The per cents of correct responses for the vertical columns are always smaller than those in the horizontal, but this is to be expected since there are ten items in the vertical while there are only four items in the horizontal. It is also interesting to note that the per cents of perfect scores in Form B are consistently higher than those for Form A. This is another indication that Part 1 of Form B is less difficult for the pupils than Part 1 of Form A. In Form A in the horizontal per cents, the highest per cents of pupils made a score of three, while in Form B the highest per cent occurs in a score of four. The lowest per cents for any score occur in the score of zero. In the vertical, the highest per cent of scores for both Forms A and B occurs in the score of eight.

Aside from showing the distribution of horizontal and vertical scores in Part I, these tables perform another function. The horizontal per cents show the degree of difficulty for each of the four gases. The easiest property in all the horizontal tables is item 4 (the same weight as air). This was to be expected, since not a single gas listed in the tests has the same weight as air. Item I on color ranks second in all cases except one, in which item 10 at 84 per cent in Table XXXV outranks it. In Form A, the most difficult item vacillates between item 3 and item 5, both of which have to do with weight. One would think that these should not be the most difficult items, since the atomic weights of these gases are given in Part I, and the pupil could easily make a comparison if he had forgotten the results of his laboratory experiments. Then, too, the molecular formula for each gas is given at the top of each column, and

TABLE XXXIV

PERCENTAGE DISTRIBUTION OF HORIZONTAL AND VERTICAL SCORES IN PART I, FORM A

3-6 Months No. of Pupils, 310

Horizontal Percentages

Scores

Ques.	No. of Pupils	4 Per Cent	No. of Pupils	3 Per Cent	No. of Pupils	2 Per Cent	No. of Pupils	1 Per Cent	No. of Pupils	0 Per Cent	No. Right	Per Cent Right	No. of Ques.
1	119	38.4	106	32.2	76	24.5	8	2.6	1	.3	954	76.9	1
2	81	26.1	120	38.7	96	31.0	12	3.9	1	.3	888	71.6	2
3	12	3.9	82	26.5	111	35.8	90	29.4	15	4.8	606	48.9	3
4	137	44.2	118	38.7	43	13.9	9	2.9	3	1.0	997	80.4	4
5	11	3.6	88	28.4	117	37.8	78	25.2	16	2.5	620	50.0	5
6	38	11.2	122	39.4	100	32.3	48	15.5	2	.6	766	61.8	6
7	36	11.6	72	23.3	95	30.7	73	23.6	34	11.0	625	50.2	7
8	23	7.4	103	33.3	115	37.1	59	19.1	10	3.2	690	55.6	8
9	52	16.8	104	33.6	89	28.7	51	16.5	14	4.5	749	60.4	9
10	114	36.8	99	32.0	59	19.1	33	10.7	5	1.6	904	72.9	10
Totals	623	20.1	1014	32.7	901	29.0	461	14.9	101	3.3	7797	62.9	

Vertical Percentages

Scores

Ques.	No. of Pup.	10 Per Cent	No. of Pup.	9 Per Cent	No. of Pup.	8 Per Cent	No. of Pup.	7 Per Cent	No. of Pup.	6 Per Cent	No. of Pup.	5 Per Cent	No. of Pup.	4 Per Cent	No. of Pup.	3 Per Cent	No. of Pup.	2 Per Cent	No. of Pup.	1 Per Cent	No. of Pup.	0 Per Cent	No. Right	P Ce Ri
O_2	57	18.4	57	18.4	74	23.9	71	22.9	32	10.3	11	3.6	6	1.9	1	.3	1	.3	0	.0	0	.0	2448	7
Cl_2	20	6.4	52	16.8	83	26 8	70	22.6	43	13.9	26	8.4	9	2.9	2	.6	1	.3	1	.3	3	1.0	2255	7
CO	9	2.9	26	8.4	27	8.7	55	17.8	69	22.3	38	12.3	34	11.0	12	3.9	13	4.2	3	1.0	24	7.8	1730	5
A	29	9.4	12	3.9	37	12.0	32	10.1	34	11.0	28	9.0	10	3.2	12	3.9	7	2.3	12	3.9	97	31.3	1364	4
Totals	115	9.3	147	11.9	221	17.8	228	18.4	178	14.4	103	8.3	59	4.8	27	2.2	22	1.8	16	1.3	124	10.0	7797	6

TABLE XXXV

PERCENTAGE DISTRIBUTION OF HORIZONTAL AND VERTICAL SCORES IN PART I, FORM A

8-10 Months No. of Pupils, 314

Horizontal Percentages

Scores

Ques.	No. of Pupils	4 Per Cent	No. of Pupils	3 Per Cent	No. of Pupils	2 Per Cent	No. of Pupils	1 Per Cent	No. of Pupils	0 Per Cent	No. Right	Per Cent Right	No. of Ques.
1	127	40.4	124	39.5	60	19.1	3	1.0	0	.0	1003	79.9	1
2	116	36.9	131	41.7	59	18.8	7	2.2	1	.3	982	78.2	2
3	19	6.1	106	33.8	99	31.5	73	23.9	17	5.4	665	53.0	3
4	187	59.6	86	27.4	31	9.9	8	5.2	2	.6	1076	85.7	4
5	21	6.7	109	34.7	111	35.4	57	18.2	16	5.1	690	55.0	5
6	30	9.6	129	41.1	121	38.5	32	10.2	2	.6	781	62.2	6
7	46	14.7	98	31.2	106	33.8	47	15.0	17	5.4	737	58.7	7
8	23	7.3	118	37.6	111	35.4	32	16.6	10	3.2	720	57.3	8
9	56	17.8	110	35.0	91	29.0	44	14.0	13	4.1	780	62.1	9
10	173	55.1	96	30.6	33	10.5	9	2.9	3	1.0	1055	84.0	10
Totals	798	25.4	1107	35.3	322	26.2	332	10.6	81	2.6	8489	67.6	

Vertical Percentages

Scores

Ques.	No. of Pup.	10 Per Cent	No. of Pup.	9 Per Cent	No. of Pup.	8 Per Cent	No. of Pup.	7 Per Cent	No. of Pup.	6 Per Cent	No. of Pup.	5 Per Cent	No. of Pup.	4 Per Cent	No. of Pup.	3 Per Cent	No. of Pup.	2 Per Cent	No. of Pup.	1 Per Cent	No. of Pup.	0 Per Cent	No. Right	C R
O_2	83	26.4	44	14.0	74	23.6	62	19.7	34	10.9	10	3.2	4	1.3	1	.3	1	.3	0	.0	1	.3	2527	
Cl_2	16	5.1	33	10.5	92	29.3	85	27.0	44	14.0	19	6.1	18	5.7	3	1.0	2	.6	1	.3	1	.3	2233	
CO	7	2.2	25	8.0	56	17.8	62	19.7	54	17.2	44	14.0	43	13.7	9	2.9	2	.6	2	.6	10	3.2	1926	
A	44	14.0	24	7.6	60	19.1	33	10.5	35	11.1	18	5.7	18	5.7	16	5.1	5	1.6	6	1 9	55	17.5	1803	
Totals	150	11.9	126	10.0	282	22.5	242	19 3	167	13.3	91	7.2	83	6.6	29	2.3	10	.8	9	.7	67	5.3	8489	

TABLE XXXVI

PERCENTAGE DISTRIBUTION OF HORIZONTAL AND VERTICAL SCORES IN PART I, FORM A

3-10 Months No. of Pupils, 624

Horizontal Percentages

Scores

Ques.	No. of Pupils	4 Per Cent	No. of Pupils	3 Per Cent	No. of Pupils	2 Per Cent	No. of Pupils	1 Per Cent	No. of Pupils	0 Per Cent	No. Right	Per Cent Right	No. of Ques.
1	246	39.4	230	36.9	136	21.8	11	1.8	1	.2	1957	78.5	1
2	197	31.6	251	40.2	155	24.8	19	3.0	2	.3	1870	75.0	2
3	31	5.0	188	30.1	210	33.7	163	26.1	32	5.1	1271	51.0	3
4	324	52.0	204	32.7	74	11.9	17	2.7	5	.9	2073	83.1	4
5	32	5.1	197	31.6	228	36.5	135	21.6	32	5.1	1310	52.5	5
6	68	11.0	251	40.2	221	35.4	80	12.8	4	.6	1547	62.0	6
7	82	13.1	170	27.2	201	32.2	120	19.2	51	8.2	1360	54.5	7
8	46	7.4	221	35.4	226	36.2	111	17.8	20	3.2	1410	56.5	8
9	108	17.3	214	34.3	180	28 9	95	15.2	27	4.3	1529	61.3	9
10	287	46.0	195	31.3	92	14.7	42	6.7	8	1.3	1959	78.6	10
Totals	1421	22.8	2121	34.0	1723	27.6	793	12.7	182	2.9	16,286	65.3	

Vertical Percentages

Scores

Ques.	No. of Pup.	10 Per Cent	No. of Pup.	9 Per Cent	No. of Pup.	8 Per Cent	No. of Pup.	7 Per Cent	No. of Pup.	6 Per Cent	No. of Pup.	5 Per Cent	No. of Pup.	4 Per Cent	No. of Pup.	3 Per Cent	No. of Pup.	2 Per Cent	No. of Pup.	1 Per Cent	No. of Pup.	0 Per Cent	No. Right
O_2	140	22.4	101	16.2	148	23.7	133	21.3	66	10.6	21	3.4	10	1.6	2	.3	2	.3	0	.0	1	.2	4975
Cl_2	36	5.8	85	13.6	175	28.1	155	24.8	87	14.0	45	7.2	27	4.3	5	.8	3	.5	2	.3	4	.6	4488
CO	16	2.5	51	8.2	83	13.3	117	18.8	123	19.7	82	13.1	77	12.3	21	3.4	15	2.4	5	.8	34	5.5	3656
A	73	11.7	36	5.8	97	15.5	65	10.4	69	11.1	46	9.4	28	4.5	28	4.5	12	1.9	18	2.9	152	24.4	3167
Totals	265	10.6	273	10.9	503	20.2	470	18.8	345	13.8	194	7.8	142	5.7	56	2.2	32	1.3	25	1.0	191	7.7	16,286

TABLE XXXVII

PERCENTAGE DISTRIBUTION OF HORIZONTAL AND VERTICAL SCORES IN PART I, FORM B

3-6 Months No. of Pupils, 276

Horizontal Percentages

Scores

Ques.	No. of Pupils	4 Per Cent	No. of Pupils	3 Per Cent	No. of Pupils	2 Per Cent	No. of Pupils	1 Per Cent	No. of Pupils	0 Per Cent	No. Right	Per Cent Right	No. of Ques.
1	151	54.7	78	28.3	32	11.6	15	5.4	0	.0	917	83.1	1
2	117	42.4	72	26.1	54	19.6	25	9.1	8	2.9	817	74.0	2
3	87	31.5	124	44.9	42	15.2	18	6.5	5	1.8	822	74.5	3
4	205	74.3	51	18.5	13	4.7	7	2.5	0	.0	1006	91.1	4
5	80	29.0	123	44.6	48	17.4	21	7.6	4	1.4	806	73.0	5
6	66	23.9	79	28.6	83	30.0	41	14.9	7	2.5	708	64.1	6
7	81	29.3	86	31.1	72	26.0	28	10.1	9	3.3	754	68.3	7
8	42	15.2	75	27.2	79	28.6	63	22.8	17	6.2	614	55.6	8
9	74	26.8	78	28.3	61	22.1	50	18.1	13	4.7	702	63.6	9
10	112	40.6	65	23 5	51	18.5	29	10.5	19	6.9	774	70.1	10
Totals	1015	36.8	831	30.1	535	19.4	297	10.8	82	3.0	7920	71.7	

Vertical Percentages

Scores

Ques.	No. of Pup.	10 Per Cent	No. of Pup.	9 Per Cent	No. of Pup.	8 Per Cent	No. of Pup.	7 Per Cent	No. of Pup.	6 Per Cent	No. of Pup.	5 Per Cent	No. of Pup.	4 Per Cent	No. of Pup.	3 Per Cent	No. of Pup.	2 Per Cent	No. of Pup.	1 Per Cent	No. of Pup.	0 Per Cent	No. Right	Per Cent Right
H_2	48	17.4	61	22 1	74	26.8	54	19.6	24	8.7	9	3.3	4	1.4	2	.7	0	.0	0	.0	0	.0	2210	80.0
N_2	25	9.0	23	8.3	60	21.7	47	17.0	34	12.3	34	12.3	25	9.0	12	4.3	4	1.4	0	.0	12	4.3	1784	64.6
CO_2	51	18.5	56	20.3	43	15.6	42	15.2	24	8.7	19	6.9	19	6.9	4	1.4	4	1.4	2	.7	12	4.3	1989	72.0
He	66	23.9	34	12.3	39	14.1	36	13.0	34	12.3	21	7.6	16	5.8	8	2.9	4	1.4	2	.7	16	5.8	1937	70.2
Totals	190	17.2	174	15.8	216	19.6	179	16.2	116	10.5	83	7.5	64	5.8	26	2.4	12	1.1	4	.4	40	3.6	7920	71.7

TABLE XXXVIII

PERCENTAGE DISTRIBUTION OF HORIZONTAL AND VERTICAL SCORES IN PART I, FORM B

8-10 Months No. of Pupils, 308

Horizontal Percentages

Scores

Ques.	No. of Pupils	4 Per Cent	No. of Pupils	3 Per Cent	No. of Pupils	2 Per Cent	No. of Pupils	1 Per Cent	No. of Pupils	0 Per Cent	No. Right	Per Cent Right	No. of Ques.
1	204	66.2	71	23.1	26	8.4	6	1.9	1	.3	1087	88 3	1
2	157	44.5	92	29.9	55	17.9	19	6.2	5	1.6	953	77.4	2
3	105	34.1	119	38 6	56	21.4	15	4.9	3	.9	924	75.0	3
4	225	73.1	51	16.6	21	6.8	6	1.9	5	1.6	1101	89.4	4
5	91	29.5	127	41.2	69	22.4	18	5.8	3	1.0	901	73.2	5
6	79	25.7	79	25.7	84	27.3	46	14.9	20	6.5	767	62.3	6
7	94	30.5	93	30.2	66	21.4	40	13.0	15	4.9	827	67.2	7
8	51	16.6	71	23.1	90	29 2	70	22.7	26	8.4	667	54.2	8
9	79	25.7	96	31.2	68	22.1	46	15.0	19	6.0	786	63.8	9
10	163	52.9	56	18.2	55	17.9	22	7.1	12	3.9	952	77.3	10
Totals	1228	39.9	859	27.8	600	19.5	288	9.6	109	3.5	8965	72.8	

Vertical Percentages

Scores

Ques.	No. of Pup.	10 Per Cent	No. of Pup.	9 Per Cent	No. of Pup.	8 Per Cent	No. of Pup.	7 Per Cent	No. of Pup.	6 Per Cent	No. of Pup.	5 Per Cent	No. of Pup.	4 Per Cent	No. of Pup.	3 Per Cent	No. of Pup.	2 Per Cent	No. of Pup.	1 Per Cent	No. of Pup.	0 Per Cent	No. Right
H_2	30	9.7	79	25.7	93	30.2	61	19.8	27	8.8	9	2.9	7	2.3	2	.6	0	.0	0	.0	0	.0	2423
N_2	35	11.4	34	11.0	50	16.2	62	20.1	38	12.3	38	12.3	18	5.8	17	5.5	7	2.3	1	.3	8	2.6	2046
CO_2	75	24.4	53	17.2	42	13.6	44	14.3	35	11.4	27	8.8	10	3.2	3	1.0	7	2.3	6	1.9	6	1.9	2285
He	78	25.3	54	17.5	45	14.6	42	13.6	21	6.8	16	5.2	9	2.9	10	3.2	6	1.9	7	2.3	20	6.5	2211
Totals	218	17.7	220	17.9	230	18.7	209	16.2	121	9.8	90	7.3	44	3.6	32	2.6	20	1.8	14	1.1	34	2.8	8965

TABLE XXXIX

Percentage Distribution of Horizontal and Vertical Scores in Part I, Form B

3-10 Months No. of Pupils, 584

Horizontal Percentages

Scores

Ques.	No. of Pupils	4 Per Cent	No. of Pupils	3 Per Cent	No. of Pupils	2 Per Cent	No. of Pupils	1 Per Cent	No. of Pupils	0 Per Cent	No. Right	Per Cent Right	No. of Ques.
1	355	60.8	149	25 3	58	9.9	21	3.6	1	.2	2004	85.8	1
2	254	43.5	164	28.1	109	18.7	44	7.5	13	2.2	1770	75.8	2
3	192	32.9	243	41.3	108	18.5	33	5.7	8	1.4	1746	74.7	3
4	430	73.6	102	17.5	34	5.8	13	2.2	5	.9	2107	90.2	4
5	171	29.3	250	42.8	117	20.0	39	6.7	7	1.2	1707	73.1	5
6	145	24.8	158	27.1	167	28 6	87	14.9	27	4.6	1475	63.1	6
7	175	30.0	179	30.7	138	23.6	68	11.5	24	4.1	1581	77.7	7
8	93	15.9	145	25.0	169	28.9	133	22.8	43	7.4	1281	54.8	8
9	153	26.2	174	29.8	129	22.1	96	16.4	32	5.5	1488	63.7	9
10	275	47.1	121	20.7	106	18.2	51	8.7	31	5 3	1726	73.9	10
Totals	2243	38.4	1686	28.9	1135	19.4	585	10.0	191	3 3	16,885	72.3	

Vertical Percentages

Scores

Ques.	No. of Pup.	10 Per Cent	No. of Pup.	9 Per Cent	No. of Pup.	8 Per Cent	No. of Pup.	7 Per Cent	No. of Pup.	6 Per Cent	No. of Pup.	5 Per Cent	No. of Pup.	4 Per Cent	No. of Pup.	3 Per Cent	No. of Pup.	2 Per Cent	No. of Pup.	1 Per Cent	No. of Pup.	0 Per Cent	No. Right	Per Cent Right
H_2	78	13.4	140	2.4	167	28.6	115	19.7	51	8.7	18	3.1	11	1.9	4	.7	0	.0	0	.0	0	.0	4633	79.3
N_2	60	10.3	57	9.8	110	18.8	109	18 7	72	12.3	72	12.3	43	7.4	29	5.0	11	1.9	1	.2	20	3.4	3830	65.6
CO_2	126	21.6	109	18.7	85	14.6	86	14.7	59	10.1	46	7.9	29	5.0	7	1.2	11	1.9	8	1.4	18	3.1	4374	73.2
He	144	24.7	88	15.1	84	14.4	78	13.4	55	9.4	37	6.3	25	4.3	18	3.1	10	1.7	9	1.5	36	6.2	4148	71.0
Totals	408	17.4	394	16.9	446	19.1	388	16.6	237	10.1	173	7.4	108	4.6	58	2.5	32	1.4	18	.8	74	3.1	16,885	72.3

this should have aided the pupil in making his comparisons. In Form B, item 8 on "A lighted stick thrust into it goes out," is the most difficult property in each case. A study of three closely related properties in items 6, 7, and 8 reveals some interesting facts. In Form A, item 7, "Burns in air," proves to be the most difficult, while the same item in Form B is the least difficult of the three items. The reason for this contrast lies in the fact that Form A contains two gases which support combustion, while Form B does not have a single gas which supports combustion. The pupil who thinks of a gas as supporting combustion, thinks of the gas as burning, too. This statement is borne out by an examination of the per cent of correct responses for the item in connection with these various gases in Tables XXVII and XXIX. In each case those gases such as oxygen and chlorine which support combustion, have lower per cents of correct responses than do those gases which burn or those which do not support combustion. In the case of hydrogen in Form B, which burns, the item, "Burns in air," is the easiest of the three items rather than the most difficult. The per cents for item 9 on the solubility of the gases maintain practically uniform figures in all the tables, since the per cents vary over a very narrow range from 60.4 to 63.8.

In the vertical per cents in Form A, oxygen receives by far the highest per cent of perfect scores. The rank order of difficulty from the least difficult to the most difficult is oxygen, chlorine, carbonmonoxide, and argon. Since argon is the most difficult item, it is interesting to note that the highest per cent of zero scores was made here and that this per cent, 31.3, also ranks highest among the eleven scores for argon. In the vertical per cents for Form B, helium occupies a rather unique position because it ranks first in the per cent of perfect responses, while at the same time it ranks first in the highest per cent of zero scores and also ranks third in the total per cents of correct responses. The rank order of gases from the least difficult to the most difficult is hydrogen, carbonmonoxide, helium, and nitrogen. It is interesting to note that the properties of a common gas like nitrogen prove to be more difficult than those of a rare gas like helium. The prominence of the use of helium at the present time no doubt accounts for nitrogen's taking second place

to helium in the results of this test. Although oxygen in Form A has a slightly higher per cent of correct responses than hydrogen in Form B, yet fewer pupils made lower scores such as 3, 2, 1, and 0 for hydrogen than they did for oxygen. This is evidenced by the fact that not a single pupil made a score of 3, 2, 1, or 0 in hydrogen while this is not true for oxygen.

The diagnostic value of Part I in Forms A and B is shown in this analysis in two general ways. First, the total per cent of correct responses for each horizontal line indicates the degree of difficulty of each of the properties, such as color, odor, etc., while the total per cents of correct responses in the vertical columns indicate the degree of difficulty for each gas. For example, in the total per cents of correct responses for the property of weight in the tables of horizontal percentages, the per cents for properties numbered 3 and 5 are nearly equal in each table while property 4 always has a much higher value than properties 3 and 5. This indicates that one aspect of the weight of the gas is less difficult for the pupils than the other which occurs in the properties numbered 3 and 5. This may mean that those pupils who answered number 4 correctly, but failed on properties 3 and 5, did not remember the facts about relative weights of the gases compared to the weight of air and did not know how to make the comparison when the essential data were given in the exercise.

In the two closely related properties which appear in question 6, 7, and 8, the difference in the per cents of correct responses for 6 and 7 should indicate that a part of the pupils are confusing the terms, "supports combustion" and "burns in air." If there is no confusion in meaning, then all those pupils who answered the one item correctly should have answered the other correctly.

The second general method of showing the diagnostic value of Part I of each test is shown in this table analysis by the per cents of pupils who make perfect, partially perfect, and zero scores on the series of properties and the group of gases. For example, in Table XXXVI for Form A, for the 3-10 month period, 52 per cent of the group made a perfect score of 4 on property number 4, while only 5.1 per cent of the pupils made perfect scores on items 3 and 4. This should indicate that only

a few of the pupils had really mastered the technique of comparing the densities of gases with that of air. A statement made in the preceding paragraph concerning the confusion of the meaning of the terms "burns" and "supports combustion" is verified when it is observed that only 11 per cent and 13.1 per cent of the pupils made perfect scores of four on properties 6 and 7. Besides pointing out the per cents of pupils making perfect and partially perfect scores, this type of analysis shows the per cents of pupils who made zero scores on the properties and on the gases.

5. Types of Error in Part I of Forms A and B

An analysis of the errors made in Part I of each form shows that there can be but two types of error: omissions and the wrong answer. Tables XL-XLII and LXXIX-LXXXI record the number of pupils making omissions and the number of pupils making incorrect responses tor each question. This total of wrong responses includes omissions. The writer constructed these tables with two purposes in mind: the first purpose was to determine whether pupils followed the directions which requested them to omit questions whose answers they did not know. In other words, the first purpose was to determine to what extent guessing had been eliminated by specifications in the directions. The second purpose was to check again the accuracy of the figures in Tables XXVII and XXIX. This was done by comparing the number wrong for each item in the 3-10 month period with the numbers of correct responses in Tables XXVII and XXIX. These numbers of correct responses were subtracted from the number of pupils in the group thus giving the numbers of wrong responses.

Table XL reads as follows: in question 1 on oxygen, of a total of 1 wrong there was 1 omission; in the case of chlorine there were five omissions out of a total of 51 wrong, etc. This table shows omissions for every one of the forty questions with the greatest number occurring under argon and carbonmonoxide. The total number of pupils making the 1720 omissions is 140 or 45.1 per cent of the pupils. The average number of omissions is 12.3 per pupil.

TABLE XL

TYPES OF ERROR IN FORM A, PART I FOR THE 3-6 MONTH PERIOD
Number of Pupils, 310

No. of Q.	O_2 Omissions	O_2 No. Wrong	Cl_2 Omissions	Cl_2 No. Wrong	CO Omissions	CO No. Wrong	A Omissions	A No. Wrong
1	1	1	5	51	26	79	110	149
2	1	3	5	32	27	152	110	164
3	1	156	5	55	32	218	107	204
4	3	38	7	14	35	55	116	137
5	3	128	8	55	37	240	118	195
6	1	25	12	169	34	111	126	169
7	5	142	17	117	40	179	127	175
8	3	37	21	185	37	124	132	203
9	9	58	20	126	48	118	134	189
10	7	61	14	41	47	80	129	153
Total	34	649	114	845	363	1356	1209	1738

Grand total of omissions 1720
Number of pupils making the omissions 140
Average number of omissions per pupil 12.3

TABLE XLI

TYPES OF ERROR IN FORM A, PART I, FOR THE 8-10 MONTH PERIOD
Number of Pupils, 314

No. of Q.	O_2 Omissions	O_2 No. Wrong	Cl_2 Omissions	Cl_2 No. Wrong	CO Omissions	CO No. Wrong	A Omissions	A No. Wrong
1	1	4	3	69	9	74	59	107
2	3	12	2	24	13	113	64	125
3	8	154	7	52	12	191	61	183
4	5	33	7	14	12	47	64	97
5	6	137	8	56	13	210	67	161
6	2	18	8	220	14	112	75	127
7	4	119	11	91	16	171	74	134
8	4	39	11	202	17	135	76	161
9	7	65	14	153	20	117	73	137
10	7	28	5	15	20	51	73	104
Total	47	609	76	896	146	1221	686	1336

Grand total of omissions 955
Number of pupils making omissions 89
Average number of omissions per pupil 10.7

TABLE XLII

TYPES OF ERROR IN FORM A, PART I, FOR THE 3-10 MONTH PERIOD
Number of Pupils, 624

No. of Q.	O_2		Cl_2		CO		A	
	Omissions	No. Wrong	Omissions	No. Wrong	Omissions	No. Wrong	Omissions	No. Wrong
1	2	5	8	120	35	153	169	256
2	4	15	7	56	40	265	174	289
3	9	310	12	107	44	209	168	387
4	8	71	14	28	47	102	180	234
5	9	265	16	111	50	450	185	356
6	3	43	20	389	48	223	201	296
7	9	261	28	208	56	350	201	309
9	16	123	34	279	68	235	207	326
10	14	89	19	56	67	131	202	257
Totals	81	1258	190	1741	509	2577	1895	3074
Grand Total of Omissions							2675	
Number of Pupils Making the Omissions							229	
Average Number of Omissions per Pupil							11.6	

This high average per pupil is due to the fact that many of the pupils omitted all ten items under argon while others omitted all or a great part of the ten items under CO. When it is considered that as high as 45 per cent of the pupils omitted questions, surely the number of pupils in this 45 per cent group who guessed must, indeed, be very small. To what extent there was guessing among the other 55 per cent of the group the writer has no means of knowing. Probably the per cent of guessers in the 55 per cent group is just as small as it is in the 45 per cent group. For the writer's purpose, however, these tables present concrete evidence which shows that there is a very strong tendency away from guessing.

The number of omissions during the 8-10 month testing period is considerably lower than that for the preceding period. This is to be expected since one or two of these gases may not have been studied during the first semester. Although the number of pupils making omissions had been materially reduced, yet the average per pupil was only reduced 1.6 questions. This was caused by these pupils omitting all ten items on argon.

The reduction in the number of pupils making omissions in the second test compared with that of the prior test is not

nearly so marked in Form B as it is in Form A. The average number of ommissions per pupil increases from the 3-6 month period to the 8-10 month period. The fact that helium is a much less difficult gas for pupils to know than argon accounts for the lower number of omissions and for the increase in average omissions. For the 3-10 month period the number of pupils making omissions in Form B is 142 while in From A it is 229. The average number of omissions per pupil is about the same in both tests, 11.5 per cent for Form B and 11.6 per cent for Form A.

The tables on the types of error in Form B are contained in the appendix. Since the data on types of error have been compared with those of Form B very frequently and since the resemblance in these data for both Forms is so similar no space will be given over to a separate discussion of the types of error in Form B in this chapter nor in the appendix. The writer feels that to make such a separate treatment of this portion of the data would necessitate needless repetition both in the presentation of similar facts and in the explanation and significance of said facts.

The data presented in this section on the types of error made in Part I of Forms A and B show that the directions for Part I of each test have been instrumental in keeping the element of guessing at the minimum. Eliminating the guessing factor as much as possible increases the diagnostic value of the test.

6. Types of Error in Part II of Forms A *and B*

When the errors made by the pupils in Part II of Forms A and B were studied, every error was listed on the master sheet. These errors were then classified and placed in condensed form in Tables XLIII-XLIX and LXXXI-LXXXVIII. For each question, the total number and per cent of pupils having the question wrong are recorded together with the different types of error, the number of times they occur, and the per cents these errors are of the total number of pupils in the group.

Table XLIII and those which succeed it read as follows: Of the 310 pupils in the 3-6 month group, 110 pupils, or

33.5 per cent of the pupils, failed to answer question 1 correctly; of the 314 pupils in the 8-10 month period, 47 pupils, or 15 per cent of the group failed the question; and of all the pupils in the 3-10 month group 157, or 25.2 per cent of the pupils failed to obtain the correct answer. Of the 110 mistakes made on this question in the first group, 36 of them, or 11.6 per cent of the group omitted the question. The succeeding items are read in the same manner. At the bottom of the column of question 1, three miscellaneous types of error comprising five separate errors are listed for the 3-6 month group; one miscellaneous type comprising one error for the 8-10 month group; and four miscellaneous types comprising six errors in the 3-10 month group. The sum of the number of errors for each question and the sum of the per cents of errors for each question will equal the number wrong and the per cent wrong respectively, each of which is listed at the top of each column and underlined.

In question 1, the greatest number of errors is made in omissions and in writing Na_2O as NaO_2. The omission signifies that the pupil did not know the principle of writing the formula and therefore omitted it or he thought the formula correct as it stands. When blanks are provided for writing these formulas, as they will be in the final tests and as they are in Form X, the scorer will know whether the pupil thought the formula to be correct as it stands or omitted it. The number of omissions in the valence questions will be materially reduced as they have been in Form X. For example, it is noted in question 1 of Table LVII that only one omission is recorded for it while the formula KO as it stands has been copied seven times. Since this condition exists throughout all the questions in valence in Form X, the writer is justified in maintaining that a large proportion of these omissions are not omissions at all but are errors caused by the pupils' believing the formula correct as it stands. Then, too, the total numbers of pupils for each of these three groups who omitted practically all five of these questions because they did not know the principle of valence, only number 28, 11, and 39 respectively.

The error of writing Na_2O as NaO_2 is the most common error because the misplacing of a subscript represents the

TABLE XLIII

TYPES OF ERROR IN VALENCE IN FORM A

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 310 No. Wrong	% Wrong	No. of Types	8-10 Months No of Pupils, 314 No. Wrong	% Wrong	No. of Types	3-10 Months No. of Pupils, 624 No. Wrong	% Wrong
1.	Totals	110	33.5		47	15.0		157	25.2
	Omissions	36	11.6		15	4.8		51	8.2
	$Na\ O_2$	37	11.9		18	5.7		55	8.8
	$Na_3\ O_2$	7	2.3		2	.6		9	1.4
	Na_3O	5	1.6		3	1.0		8	1.3
	$Na\ O_3$	5	1.6		1	.3		6	1.0
	Na_2O_3	3	1.0		2	.6		5	.8
	Na_2O_2	2	.6		3	1.0		5	.8
	$Na\ O\ H$	3	1.0		1	.3		4	.6
	Na_2I_2	3	1.0		0	.0		3	.5
	$Na\ O$	2	.6		0	.0		2	.3
	$2\ Na\ O$	1	.3		1	.3		2	.3
	$Na + O_2$	1	.3		0	.0		1	.2
	3 Miscellaneous types	5	1.6	1	1	.3	4	6	1.0
2.	Totals	142	45.8		73	23.3		215	34.5
	Omissions	66	21.3		20	6.4		86	13.8
	$Al(NO_3)_2$	24	7.7		15	4.8		39	6.3
	Al_3NO_3	18	5.8		15	4.8		33	5.3
	$Al_2\ NO_3$	18	5.8		11	3.5		29	4.6
	$Al\ NO_3$	6	1.9		4	1.3		10	1.6
	$3\ Al\ NO_3$	3	1.0		1	.3		4	.6
	$Al + (NO_3)_2$	1	.3		0	.0		1	.2
	$3\ Al\ NO$	1	.3		0	.0		1	.2
	4 Miscellaneous types	5	1.6	7	7	2.2	8	12	1.9
3.	Totals	145	46.8		78	24.8		223	35.7
	Omissions	62	20.0		19	6.1		81	13.0
	Ca_2PO_4	34	11.0		17	5.4		51	8.2
	Ca_3PO_4	17	5.5		21	6.7		38	6.1
	$Ca\ (PO_4)_2$	13	4.2		5	1.6		18	2.9
	$Ca_2(PO_4)_3$	2	.6		5	1.6		7	1.1
	Ca_6PO_4	0	.0		5	1.6		5	.8
	$Ca_2(PO_4)_2$	3	1.0		1	.3		4	.6
	$2\ Ca\ PO_4$	4	1.3		0	.0		4	.6
	$Ca\ PO_4$	0	.0		1	.3		1	.2
	9 Miscellaneous types	10	3.2	4	4	1.3	10	14	2.2

TABLE XLIII (*Continued*)

TYPES OF ERROR IN VALENCE IN FORM A

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 310 No. Wrong	% Wrong	No. of Types	8-10 Months No of Pupils, 314 No. Wrong	% Wrong	No. of Types	3-10 Months No. of Pupils, 624 No. Wrong	% Wrong
1.	Totals	103	33.2		71	22.6		174	27.9
	Omissions	38	12.3		13	4.1		51	8.2
	Mn_2O_4	25	8.1		20	6.4		45	7.2
	M N_2O_4	0	.0		14	4.5		14	2.2
	Mn O_3	9	2.9		1	.3		10	1.6
	Mn O_4	5	1.6		5	1.6		10	1.6
	Mn_2O	6	1.9		3	1.0		9	1.4
	Mn_4O_2	4	1.3		2	.6		6	1.0
	M N_4O_2	0	.0		4	1.3		4	1.6
	2 Mn O_2	0	.0		2	.6		2	.3
	10 Miscellaneous types	16	5.2	6	7	2.2	13	23	3.7
5.	Totals	176	56.8		115	36.6		291	46.6
	Omissions	104	33.6		42	13.4		146	23.4
	1	32	10.3		28	8.9		60	9.6
	3	14	4.5		14	4.5		28	4.5
	4	8	2.6		13	4.1		21	3.4
	6	8	2.6		7	2.2		15	2.4
	8	4	1.3		3	1.0		7	1.1
	5	0	0		5	1.6		5	.8
	7	4	1.3		0	0		4	.6
	12	1	.3		1	.3		2	.3
	0	1	.3		0	.0		1	.2
	D_2C_2	0	.0		1	.3		1	.2
	+ + + + + +	0	.0		1	.3		1	.2

simplest error the pupil could possibly make. Why the pupils should use other valences than the ones given for Na and O, is hard to explain. It may be possible that the pupil was careless in using the given valences at the top of the page and accidentally used the valence of another element. The error Na_2O_2 can be explained on other grounds since there is such a compound which the pupils have used in the preparation of oxygen. The valences of the Na and O are the same as in Na_2O, but the writing of the sodium peroxide formula involves a different valence principle for writing the formula since one of

the valence bonds connects the two oxygen atoms instead of being directly bound to the sodium atom. It is surprising that of the 624 pupils only five wrote the peroxide formula when evidence already presented and discussed in this paper tends to show that the pupil depends to a greater degree upon his memory than upon his reasoning powers. Two pupils took the trouble to copy the formula NaO and thus prove to the scorer that they did not omit the question.

In question 2, the first four errors are the most conspicuous. Two of them, Al $(NO_3)_2$ and Al_2NO_3, are hard to account for since the per cent of pupils making this error is rather high and since the subscript 2 which is used in the formulas is not given as a valence for Al or NO_3. In other words, why should so many pupils copy the wrong valence from the given data? The error Al_3NO_3 should be the most common one since it is simply a misplacement of the subscript. When a pupil writes Al $(NO_3)_3$ as $3AlNO_3$ or Al + $(NO_3)_2$ or 3AlNO, it signifies that the pupil has little or no understanding of the principle of valence.

In all the errors so far discussed in questions 1 and 2, the pupil has failed to check the total valence of the radical by multiplying the subscript number by the valence of the element or radical. If the pupils were thoroughly impressed through the teaching process that the total "plus" valence must always equal the total "minus" valence the number of errors would be materially reduced.

In the first three errors listed after omissions in question 3, the pupils have used but one of the two given valences as is indicated in the subscripts. $Ca_2(PO_4)_3$ represents only a very small per cent of the errors since one would expect it to be a most popular error for the reason that this error represents a misplacement of the subscripts as in questions 2 and 3. Again, the pupils have failed to make their total valences balance.

In question 4, the pupils in writing MnO_2 as Mn_2O_4 balanced their total valences correctly, but failed to use the smallest subscripts possible. The mistake MN_2O_4 represents the same error as Mn_2O_4 with the additional mistake of writing the wrong symbol for manganese. Why fourteen pupils should make this mistake is difficult to explain since the Mn symbol is

already given in the formula. Perhaps this error in symbol can be attributed to carelessness. The error Mn_2O represents a misplacement of the subscript.

In question 5, two is the correct answer for the valence of D. The writer does not know whether the recorded errors were caused by mistakes in one, two, or all three of the steps since the pupils made their computations in their heads and not on paper or they may have guessed at the answer.

A knowledge of the errors made by pupils in the mechanics of high school chemistry is of value to the teacher since he can change his teaching procedures and teaching emphasis so as to guard against the various types of error the pupils are most likely to make. No attempt is made here to develop the implications inferred from the foregoing statement. A full discussion of these implications is reserved for Chapter V.

The types of error made in this exercise on the principle of valence clearly indicate that the selected items test the pupil's ability to apply the principle of valence. When the pupil misplaces subscripts or uses the wrong subscript, he fails to make the total valences balance and thus violates the principles of valence. When the pupil fails to use the smallest possible subscript in balancing the total valence of each part of the formula, he is again violating the principle of valence. Question 5 tests the pupil's ability to find the valence of one part of the formula when the formula or formulas and one valence are given. This exercise is valid for diagnosis of difficulties in the principle of valence, since the two possible applications of the principle are tested in the writing of the formula with valence given and the finding of the valence when the formula and one valence are given. Furthermore, all the errors are errors of principle.

The types of error in nomenclature are listed in Table XLIV. The outstanding error for HCl is the failure to write the complete name for the compound since the word "acid" is omitted from the name. "Hypochlorous" ranks next in importance as an error. This error and all that follow are results of not knowing the principles of nomenclature.

Outside of "omissions" and "not finished" in question 7, the errors are scattered and insignificant. These errors are all

caused by lack of knowledge of the principle, since the formula K_2O has been given such names as dioxides, pentoxides, hypochlorous acid, etc.

The errors, "sodium sulphate" and "sodium sulphide" for Na_2S in question 8 are due to a lack of knowledge of the principle.

The errors sodium sulphate and sodium sulphide in question 9 are caused by two or more factors. In the first place, the symbol K is named sodium, an error which no doubt is caused by carelessness in reading the formulas. In the second place, all these errors are due to a lack of knowledge of the principle or to the pupil's not remembering the fundamental formula, or to both of these causes.

The principal errors for naming $KHSO_4$ consist of omissions, potassium sulphate, potassium hydrosulphate, and "not finished." The main difficulty here is that the pupils do not know how to express the presence of hydrogen in this acid salt. This difficulty persists in nearly all the other types of error, since the pupils name the salt as an acid instead of as an acid salt. A lack of knowledge of the principle of nomenclature shows its presence in such names as potassium hydroxide, potassium chlorate, et cetera.

The most prominent errors for naming NaClO are omissions, sodium chloride, sodium chlorate, and sodium chlorite. These and the remaining types of error are caused by the pupils' not knowing the fundamental formula, by a lack of knowledge of the principle, or by both.

Aside from the errors made in naming symbols, all the types of error violate the principles of nomenclature. With this as the criterion, the selected items in this exercise are valid for the diagnosis of difficulties encountered in naming the formulas of compounds.

Table XLV is read in the same manner as the preceding tables, but is different from them in having two extra columns, named "No. of Sub-totals" and "% of Sub-totals." The columns give the number and per cents of sub-types of error and are interpreted as follows: Of the 56 errors in "Total Prin" given in the first column of question 13, 19 are represented in "miscellaneous principle," 7 in "$FeOH_2$," etc.

TABLE XLIV

TYPES OF ERROR IN NOMENCLATURE IN FORM A

Formulas

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 310 No. Wrong	% Wrong	No. of Types	8-10 Months No. of Pupils, 314 No. Wrong	% Wrong	No. of Types	3-10 Months No. of Pupils, 624 No. Wrong	% Wrong
6.	Totals	36	11.6		12	3.8		48	7.7
	Omissions	5	1 6		1	.3		6	1.0
	Hydrochloric	14	4.5		5	1.6		19	3.0
	Hypochlorous Acid	6	1.9		0	.0		6	1.0
	Chlorine	2	.6		2	.6		4	.6
	Chloride	2	.6		0	.0		2	.3
	Hydrochlorous	1	.3		1	.3		2	.3
	Hydrochloride	0	.0		2	.6		2	.3
	Hydrogen chlorine	1	.3		0	.0		1	.2
	Chlorous acid	1	.3		0	.0		1	.2
	4 miscellaneous types	4	1.3	1	1	.3	5	5	.8
7.	Totals	106	34.2		34	10.8		140	22.4
	Omissions	64	20 6		20	6.4		84	13.5
	Not finished	12	3.9		3	1.0		15	2.4
	Potassium dioxide	7	2.3		6	1.9		13	2.1
	Potassium oxlate	6	1.9		0	.0		6	1.0
	Calcium oxide	2	.6		0	.0		2	.3
	Potassium pentoxide	2	.6		0	.0		2	.3
	Hypochlorous acid	1	.3		0	.0		1	.2
	Sodium oxide	1	.3		0	.0		1	.2
	Caustic potash	1	.3		0	.0		1	.2
	Kerosine	1	.3		0	.0		1	.2
	Water	0	.0		1	.3		1	.2
	9 miscellaneous types	9	2.9	4	4	1.3	13	13	2.1
8.	Totals	158	51.0		104	33.1		262	42.0
	Omissions	30	9.7		14	4.5		44	7.1
	Sodium sulphate	55	17.7		50	15.9		105	16.8
	Sodium sulphite	21	6.8		22	7.0		43	6.9
	Sodium sulphur	6	1.9		7	2.2		13	2.1
	Not finished	9	2.9		1	.3		10	1.6
	Sodium nitrate	5	1.6		0	.0		5	.8
	Sodium nitrite	4	1.3		0	.0		4	.6
	Sodium nitrogen	3	1.0		0	.0		3	.5
	Sodium sulphurous	2	.6		0	.0		2	.3
	Salt	1	.3		0	.0		1	.2
	Calcium sulphate	1	.3		0	.0		1	.2
	Sodium bisulphide	1	.3		1	.3		2	.3
	20 miscellaneous types	20	6.5	9	9	2.9	29	29	4.6
9.	Totals	200	64.5		157	50.0		357	57.2
	Omissions	79	25.5		19	6.1		98	15.7
	Sodium sulphate	52	16.8		76	24.2		128	20.5
	Sodium sulphide	30	9.7		38	12.1		68	10.9
	Not finished	4	1.3		3	1.0		7	1.1
	Sulphate	3	1.0		2	.6		5	.8
	Sodium sulphuric acid	3	1.0		1	.3		4	.6
	Sodium trioxide	2	.6		2	.6		4	.6
	Sodium sulphurous acid	2	.6		2	.6		4	.6
	Sodium sulphurous	1	.3		2	.6		3	.5
	Trioxide	3	1.0		0	.0		3	.5
	Sodium sulph	1	.3		1	.3		2	.3
	Sodium sulphur dioxide	1	.3		1	.3		2	.3
	Sodium chlorite	0	.0		1	.3		1	.2
	Anhydride	1	.3		0	.0		1	.2
	18 miscellaneous types	18	5.8	9	9	2.9		27	4.3

TABLE XLIV (*Continued*)

TYPES OF ERROR IN NOMENCLATURE IN FORM A

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 310 No. Wrong	% Wrong	No. of Types	8-10 Months No. of Pupils, 314 No. Wrong	% Wrong	No. of Types	3-10 Months No. of Pupils, 624 No. Wrong	% Wrong
10.	Totals	243	78 4		170	54.1		413	66.2
	Omissions	98	31.6		45	14.3		143	22.9
	Potassium sulphate	34	17.4		43	13.7		97	15.5
	Potassium Hydrosulphate	14	4.5		35	11.1		49	7.9
	Not finished	19	6.1		12	3.8		31	5 0
	Potassium sulphide	3	1.0		5	1.6		8	1.3
	Potassium sulphuric acid	6	1.9		2	.6		8	1.3
	Potassium hyposulphate	3	1.0		4	1.3		7	1.1
	Potassium per sulphate	4	1.3		2	.6		6	1.0
	Potassium sulphite	4	1.3		1	.3		5	.8
	Potassium hydroxide	4	1.3		1	.3		5	.8
	Potassium hydrosulphuric acid	4	1.3		0	.0		4	.6
	Potassium hydrogen sulphide	0	.0		2	.6		2	.3
	Potassium sulphur oxide	2	.6		0	.0		2	.3
	Potassium chlorate	2	.6		0	.0		2	.3
	Potassium hyposulphate	2	.6		0	.0		2	.3
	Potassium hydrosulphide	0	.0		2	.6		2	.3
	Potassium bisulphide	1	.3		1	.3		2	.3
	Potassium per hydrosulphate	1	.3		1	.3		2	.3
	22 miscellaneous types	22	7.1	14	14	4.5	36	36	5.8
11.	Totals	290	93.6		282	89.8		572	91.7
	Omissions	56	18.1		29	9.2		85	13.6
	Sodium chloride	76	24.5		69	22.0		145	23.2
	Sodium chlorate	62	20.0		62	19.2		124	19.9
	Sodium chlorite	16	5 2		37	11.8		53	8.5
	Sodium per chlorate	7	2.3		20	6.4		27	4.3
	Not finished	7	2.3		7	2.2		14	2.2
	Sodium chloroxide	3	1.0		7	2.2		10	1.6
	Sodium Chloric acid	3	1.0		5	1.6		8	1.3
	Sodium chlorous acid	5	1.5		2	.6		7	1.1
	Sodium chloride oxide	3	1.0		3	1.0		6	1.0
	Sodium hypo chlorous	3	1.0		3	1.0		6	1.0
	Sodium chlorous	1	.3		4	1.3		5	.8
	Sodium hypochlorate	2	.6		5	1.6		7	1.1
	Sodium chlorine oxide	1	.3		3	1.0		4	.6
	Nitro chloric acid	3	1.0		1	.3		4	.6
	Sodium hypochloric acid	3	1.0		0	.0		3	.5
	Sodium chlorine	3	1.0		0	.0		3	.5
	Sodium carbonate	2	.6		3	1.0		5	.8
	Sodium hypochloride	0	.0		2	.6		2	.3
	Sodium chloride acid	2	.6		0	.0		2	.3
	Nitrogen chloric acid	2	.6		0	.0		2	.3
	30 miscellaneous types	30	9.7	21	20	6.4	44	50	8 0

TABLE XLV

Types of Error in Formulas in Form A

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 310				8-10 Months No. of Pupils, 314				3-10 Months No. of Pupils, 624			
		No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	Sub-totals
13.	Totals	242		78.1		215		68.5		457		73.3	
	Omissions	64		20.6		24		7.6		88		14.1	
	Not finished	3		1.0		1		.3		4		.6	
	Misc. Principle		19		6.1		30		10.0		49		7.9
	Fe OH_2		7		2.3		0		.0		7		1.1
	Fe OH_3		5		1.6		0		.0		5		.8
	Fe H		8		2.6		2		.6		10		1.6
	Oxide		17		5.5		3		1.0		20		3.2
	Total Prin.	56		18.1		35		11.1		91		14.6	
	Misc. Valence		19		6.1		47		15.0		66		10.6
	Fe OH		51		16.5		46		15.0		97		15.5
	Fe $(OH)_2$		38		12.3		60		19.1		88		15.7
	Total Valence	108		34.8		153		48.7		261		41.8	
	Symbol	1		.3		1		.3		2		.3	
	Symbol and Principle	6		1.9		1		.3		7		1.1	
	Symbol and Valence	3		1.0		0		.0		3		.5	
	Principle and Val.	1		.3		0		.0		1		.2	
14.	Totals	235		75.8		203		64.7		436		70.2	
	Omissions	48		15.5		17		5.4		65		10.4	
	Not finishd	29		9.4		7		2.2		36		5.8	
	Misc. Principle		21		6.8		13		4.1		34		5.5
	Na NO_3		79		25.5		112		35.7		191		30.6
	Total Principle	100		32.3		125		39.8		225		36.1	
	Valence	2		.6		1		.3		3		.5	
	Symbol and Principle	33		10.6		15		4.8		48		7.7	
	Principle and Valence	23		7.4		38		12.1		61		9.8	

TABLE XLV (*Continued*)

TYPES OF ERROR IN FORMULAS IN FORM A

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 310				8-10 Months No. of Pupils, 314				3-10 Months No. of Pupils, 624			
		No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals
15.	Totals	279		90.0		253		80.6		532		85.3	
	Omissions	109		35.2		38		12.1		147		23.6	
	Not finished	8		2.6		16		5.1		24		3.8	
	Misc. Principle		19		6.1		12		3.8		31		5.0
	NH_4HCO_3		1		.3		1		.3		2		.3
	Total Principle	20		6.5		13		4.1		33		5.3	
	Misc. Valence		3		1.0		4		1.3		7		1.1
	NH_4CO_3		37		11.9		70		22.3		107		17.2
	Total Valence	40		12.9		74		23.5		114		18.3	
	Misc. Symbols		4		1.3		6		1.9		10		1.6
	Am CO_3		0		.0		4		1.3		4		.6
	A CO_3		1		.3		0		.0		1		.2
	Total Symbol	5		1.6		10		3.2		15		2.4	
	Misc. Symbol and Prin.		44		14.2		24		7.6		68		10.9
	Al CO		2		.6		0		.0		2		.3
	Total Symbol and Prin.	46		14.8		24		7.6		70		11.2	
	Symbol and Valence	6		1.9		11		3.5		17		2.7	
	Misc. Prin. and Valence		36		11.6		55		17.5		91		14.6
	NH_3CO_3		9		2.9		12		3.8		21		3.4
	Total Prin. and Valence	45		14.5		67		21.3		112		18.0	

TABLE XLV (*Continued*)

TYPES OF ERROR IN FORMULAS IN FORM A

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 310				8-10 Months No. of Pupils, 314				3-10 Months No. of Pupils, 624			
		No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals
16.	Totals	197		63.6		172		54.8		369		59.2	
	Omissions	72		23.2		43		13.7		115		18.4	
	Not finished	11		3.5		5		1.6		16		2.6	
	Misc. Principle		16		5.2		3		1.0		19		3.0
	$HClO_4$		8		2.6		4		1.3		12		1.9
	$HClO_3$		19		6.1		15		4.8		34		5.5
	$HClO_2$		13		4.2		23		7.3		36		5.8
	HCl		20		6.5		15		4.8		35		5.6
	Total Principle	76		24.5		60		19.1		136		21.8	
	Valence	1		.3		2		.6		3		.5	
	Symbol	2		.6		0		.0		2		.3	
	Symbol and Principle	28		9.0		11		3.5		39		6.3	
	Principle and Valence	5		1.6		51		16.2		56		9.0	
17.	Totals	277		89.4		242		77.1		519		83.2	
	Omissions	110		35.5		66		21.0		176		28.2	
	Not finished	31		10.0		21		6.7		52		8.3	
	Misc. Principle		13		4.2		26		8.3		39		6.3
	$NaClO_3$		12		3.9		15		4.8		27		4.3
	$NaClO_2$		10		3.2		14		4.5		24		3.8
	NaClO		10		3.2		20		6.4		30		4.8
	NaCl		11		3.5		6		1.9		17		2.7
	Total Principle	56		18.1		81		25.8		137		22 0	
	Valence	2		.6		2		.6		4		.6	
	Symbol	3		1.0		2		.6		5		.8	
	Symbol and Principle	22		7.1		10		3.2		32		5.1	
	Symbol and Valence	0		.0		1		.3		1		.2	
	Misc. Prin. and Valence		28		9.0		49		15.6		77		12.3
	$NaCl_3$		14		4.5		9		2.9		23		3.7
	$NaCl_4$		11		3.5		1		.3		12		1.9
	Total Prin. and Valence	53		17.1		59		18.8		112		18.0	

In the case of $FeOH_2$ and $FeOH_3$, the pupils have failed to put parenthesis around the OH radical. For example, $FeOH_3$ should be written as $Fe(OH)_3$. In the case of oxide errors, the pupils have written the formula as ferric or ferrous oxides, thus committing another error in principle. Another important class of errors is the failure of the pupil to know the valence of ferric iron. Other pupils made errors in both principle and symbols for the element iron, while still others made errors in both principle and valence.

In question 15, the principal type of error is made in principle, in the valence of the NH_4 and CO_3 radicals, in symbols, and in combinations of these types of error as shown in "symbol" and "principle," etc.

In question 16, the most prominent error was made in principle. Not knowing the fundamental formula did not enter into these errors for the reason that this formula is given in the sample. The second important error is the one which represents a combination of "symbol and principle" type.

In question 17, aside from omission, principle ranks first in errors, while the combination type "principle and valence" ranks next. In Tables XLIV and XLV, the pupils make omissions because they do not know the principles of nomenclature and writing formulas.

In the tables on types of error which have already been discussed, it is to be noted that the types of error in the second testing (8-10 months) are usually reduced in number. This is most apparent in questions 7, 8, and 9 in Table XLIV, where quite a number of zeros are recorded for the 8-10 month testing period. Not only is there a reduction in types of error, but there is also a reduction in the numbers of pupils making errors in each of the minor types of error. Questions 9 and 10 in the same table illustrate this point. As a result of fewer types of error and the reduction in number of errors in the minor types, there is greater concentration in the principal types of error. In some instances the number of cases is greater for the principal type in the second testing period than it is in the first. Question 14 of Table XLV illustrates this point when it attributes 100 errors to "Total Principle" in the 3-6 month testing period, while in the 8-10 month testing period it attributes 125

errors to "Total Principle." A type of error which shows a decided reduction in the second testing period is that of omissions. In nearly every instance of all the questions studied, the number of omissions has been cut in two during the second testing period. This seems to indicate that a larger proportion of those pupils who omitted these questions because of lack of knowledge, have learned something of the principles involved and are therefore capable of answering the question correctly or of making some type of error other than omission.

The types of error made in this exercise on the writing of formulas from the names of compounds clearly shows that this ability is a more complex one than the ability to name formulas. These more numerous types of error can be classified into the following main types: principle of nomenclature of compounds; naming symbols; principle of valence; and failure to remember the valence of elements and radicals. Since this exercise was constructed for the purpose of testing the pupil's ability to apply the principles of nomenclature and valence to the writing of formulas, the types of error clearly show that the exercise is valid.

Questions 18-20 in Table XLVI depict the types of error made in the writing of equations where only one step is involved, that of balancing the equations. Aside from omissions, the greatest number of errors occurs in the balancing of equations. A few violated the principle of balancing equations by changing subscripts in the formulas, while a few added extra products in order to make the equation balance. This exercise is surely valid since the great majority of the errors are in omissions and balancing, while the remaining types also violate the principle of balancing equations.

In questions 21 and 22, the outstanding errors are those in valence. This error is not caused by the pupils' not knowing the valences of the elements and radicals, but by their not knowing the principle of valence sufficiently well to observe the valence from the given formulas on the left hand side of the equation. A mistake in valence, of course, produced incorrect formulas, but the error was registered under valence. Those errors which are marked "formulas" are errors in formulas other than that caused by an inaccurate knowledge of the prin-

TABLE XLVI

TYPES OF ERROR IN EQUATIONS IN FORM A

No. of Ques.	Type of Error	3-6 Months No. of Pupils, 310 No. Wrong	3-6 Months % Wrong	8-10 Months No. of Pupils, 314 No. Wrong	8-10 Months % Wrong	3-10 Months No. of Pupils, 624 No. Wrong	3-10 Months % Wrong
18.	Totals	84	27.1	59	18.8	143	22.9
	Omissions	40	12.9	18	5.7	58	9.3
	Balance	27	8.7	24	7.6	51	8.2
	Formula	17	5.5	16	5.1	33	5.3
	Product	0	.0	1	.3	1	.2
19.	Totals	96	31.0	63	20.1	159	25.5
	Omissions	56	18 1	22	7.0	78	12.5
	Balance	29	9.4	34	10.8	63	10.1
	Formula	10	3.2	6	1.9	16	2 6
	Product	0	.0	1	.3	1	.2
	Extra Product	1	.3	0	.0	1	.2
20.	Totals	94	30.3	69	22.0	163	26.1
	Omissions	59	19.0	24	7.6	83	13.3
	Balance	32	10.3	39	12.4	71	11.4
	Formula	3	1.0	5	1.6	8	1.3
	Product	0	.0	1	.3	1	.2
21.	Totals	242	78.1	215	68.5	457	73 3
	Omissions	55	17.7	19	6.1	74	11.9
	Not finished	2	.6	1	.3	3	.5
	Balance	5	1 6	10	3.2	15	2 4
	Valence	118	38.1	145	46.2	263	42 2
	Formula	48	15.5	30	9.6	78	12.5
	Product	6	1.9	7	2.2	13	2.1
	Extra Product	8	2.6	3	1.0	11	1 8
22.	Totals	246	79.4	221	70.4	467	74 9
	Omissions	87	28.1	27	8.6	114	18.3
	Not finished	4	1.3	2	.6	6	1.0
	Balance	18	5.8	22	7.0	40	6.4
	Valence	118	38.1	159	50.6	277	44.4
	Formula	15	4 8	6	1.9	21	3.4
	Product	4	1.3	1	.3	5	.8
	Extra Product	0	.0	3	1.0	3	.5
	No reaction	0	.0	1	.3	1	.2
25.	Totals	206	66.5	166	52.9	372	59.6
	Omissions	71	22 9	35	11.1	106	17.0
	Molecular	113	36.5	114	36.3	227	36.4
	Balance	15	4.8	13	4.1	28	4.5
	Formula	5	1.6	0	.0	5	.8
	Product	0	.0	1	.3	1	.2
	Extra product	2	.6	1	.3	3	.5
	Molecular Wts. only	0	.0	2	.6	2	.3

TABLE XLVI (*Continued*)

TYPES OF ERROR IN EQUATIONS IN FORM A

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 310				8-10 Months No. of Pupils, 314				3-10 Months No. of Pupils, 624			
		No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals
26	TOTALS	209		67.4		208		66.2		417		66.8	
	Omissions	103		33.9		67		21.3		172		27.6	
	Molecular Na		9		2.9		22		7.0		31		5.0
	Molecular H		34		11.0		46		14 7		80		12.8
	Molecular Na and H		7		2.3		7		2.2		14		2.2
	Total Molecular	50		16.1		75		23.9		125		20.0	
	Balance	43		13.9		36		11.5		79		12.7	
	Formula	10		3.2		17		5.4		27		4.3	
	Product	1		.3		5		1.6		6		1.0	
	Extra Product	0		.0		2		.6		2		.3	
	Molecular Wt. only	0		.0		6		1.9		6		1.0	
27.	TOTALS	195		62.9		161		51.3		356		57.1	
	Omissions	75		24.2		42		13.4		117		18.8	
	Not finished	1		.3		0		.0		1		.2	
	Molecular Zn		2		.6		3		1.0		5		.8
	Molecular H		8		2.6		11		35.0		19		3.0
	Total Molecular	10		3.2		14		4.5		24		3.8	
	Balance	11		3.5		7		2.2		18		2.9	
	Valence	80		25.8		84		26.8		164		26.3	
	Formula	4		1.3		3		1.0		7		1.1	
	Product	14		4.5		11		3.5		25		4.0	
28.	TOTALS	221		71.3		172		54.8		393		63.0	
	Omissions	129		41.6		65		20.7		194		31.1	
	Not finished	8		2.6		5		1.6		13		2.1	
	Balance	9		2.9		21		6.7		30		4.8	
	Valence	53		17.1		62		19.7		115		18.4	
	Formula	5		1.6		5		1.6		10		1.6	
	Product	17		5.5		14		4.5		31		5.0	

TABLE XLVI (*Continued*)

TYPES OF ERROR IN EQUATIONS IN FORM A

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 310				8-10 Months No. of Pupils, 314				3-10 Months No. of Pupils, 624			
		No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals
39.	TOTALS	246		79.4		197		62.7		443		71.1	
	Omissions	184		59.4		118		37.6		302		48.4	
	Not finished	10		3.2		15		4.8		25		4.0	
	Balance	2		.6		6		1.9		8		1.3	
	Valence	23		7.4		23		7.3		46		7.4	
	Formula	25		8.1		24		7.6		49		7.8	
	Product	2		.6		6		1.9		8		1.3	
	No reaction	0		.0		5		1.6		5		.8	
40.	TOTALS	290		93.6		243		77.4		533		85.4	
	Omissions	207		66.8		128		40.8		335		53.7	
	Not finished	32		10.3		28		8.9		60		9.6	
	Balance	1		.3		7		2.2		8		1.3	
	Valence	10		3.2		25		8.3		36		5.8	
	Product	4		1.3		15		4.8		19		3.0	
	Misc., Formula		33		10.6		38		12.1		71		11.4
	Formula, Ca O		1		.3		0		.0		1		.2
	Formula, Ca $(OH)_2$		2		.6		0		.0		2		.3
	Formula, Ca		7		.0		1		.3		1		.2
	Total Formula	36		11.6		29		12.4		75		12.0	

ciple of valence. For example, some changed the NH_4 radical in the product to NH_3 or to NH_2. In question 22, the errors consisted of mistakes in the SO_4 and NO_3 radicals. Although only two blanks are supplied in the test for the two formulas, and although the sample stated the kind of equation, explained and illustrated how it was written, yet a few pupils wrote in the extra products. An error in products indicates that the pupil wrote the correct formula for a compound which was not produced in this reaction. "No reaction" means that the pupil wrote those two words in the blanks.

Aside from omissions in questions 25 and 26 on making the equations molecular, the greatest proportion of errors was molecular. Since these equations were placed in the test for testing the pupils' knowledge of the principle of writing molecular equations, it can be concluded that these two equations are valid. The number of errors in balancing the equations is significant, since their per cents during the 8-10 month testing are not noticeably reduced. One would think that the simple operation of balancing equations would be mastered by that time. The error labeled "molecular Wts. only" indicates that the pupil wrote molecular weights under each molecule or atom and did nothing to make the equations molecular. In question 26, there was an increase in errors in "Molecular Na" and in "Molecular H" during the second testing period. Pupils who had learned to write molecular oxygen as O_2 applied the same principle to a solid such as Na, and wrote it as Na_2. Since the number of omissions was reduced in the second testing, it no doubt increased the per cent of correct responses as well as the number of molecular errors.

Questions 27 and 28 of the completion equation type record valence as the most difficult factor encountered. This same tendency regarding the difficulty of valence was also recorded in questions 21 and 22. Since these four questions and questions 39 and 40 are the only ones in the group of equation questions in which errors would be made in valence, it is seen that a knowledge of the principle of valence by the pupil is highly important if the pupil is to learn the mechanics of writing equations. In the completion equations, the next ranking difficulty is that of knowing the products of the reaction. Ques-

tion 28 contains no molecular errors, since both the reagents and the products are compounds, and are already molecules without the making of added changes. In question 27, however, there are two elements, zinc and hydrogen, which must be written as molecules, since that is one of the requirements stated in the directions.

Questions 39 and 40 constitute the most difficult equations of the entire group since no formulas whatsoever are given. The pupil must first of all know the formula for the reagent named in the question. It is, therefore, observed that the formula holds nearly equal or higher rank than valence. If those who did not know the formula of the reagent had known its composition, more errors would have occurred in valence, again making it the most important principle in equation writing. The specific formulas which some of the pupils wrote indicate that the pupils knew that limestone or marble is a calcium compound, but they did not know which one it is. Balancing does not occupy such a significant place in these two equations, since the registering of the principal or more important errors in the equations, such as those in formulas, valence, and products, prevents the possibility of registering errors in balancing. Had combinations of errors been recorded, those combinations containing balancing would make balancing more conspicuous than it now is.

This study of the errors made by pupils in the writing of equations shows that the abilities to balance equations and write molecular equations are tested by two kinds of exercises designed for this purpose. As the equations increase in difficulty the types of error clearly show that more than one ability is being tested. In the double decomposition equations, the ability to apply the principle of double decomposition in writing the products, the ability to apply the principles of valence in writing the formulas of the products, and the ability to balance the equation are being tested. In the writing of the complete equations two more specific abilities are tested in the operation. They are the knowledge of products and the ability to write the formulas of elements as molecules. The writing of entire equations contains all the foregoing abilities plus one more, that of knowing the formulas for the reagents.

Since this study of errors in equation writing shows that certain of the specific abilities are tested separately and that the more complex abilities are tested in steps which vary in difficulty, it has been shown that the exercise on equation writing is valid.

In Table XLVII, the most important type of error occurs in the use of signs. This difficulty is brought about by two causes: a lack of knowledge of the principle, a misunderstanding of the directions, or by both causes. In Form X, in which the directions have been revised, the per cents of errors due to "signs only" are reduced to less than one per cent. The per cents of pupils making correct responses in the revised form do not differ very much from those made in Forms A and B. In the revised form, valence plays the most prominent part. A more critical examination of the responses to these two questions in Forms A and B shows to what extent pupils, misled by the directions for questions 31 and 32, used the correct principle of writing ions in the ionic equation of question 33. The data for this analysis are as follows:

Form A

3-6 Months		8-10 Months		3-10 Months	
No. of Pupils	Per cent of Pupils	No. of Pupils	Per cent of Pupils	No. of Pupils	Per cent of Pupils
7	2.3	21	6.7	28	4.5
		Form B			
2	.7	7	2.3	9	1.5

A comparison of these figures with those on "total signs only" in Form A shows that of those pupils who made this type of error only one-fourth to one-half of said pupils had any ideas on the correct principles of writing ions. A similar comparison for Form B shows that only one-eighth to about one-fourth of the pupils who committed these errors in signs had any idea how to write ions. Furthermore, of those 28 pupils in Form A who knew something of the principle of writing ions, only one succeeded in writing the ionic equation correctly. Of the 9 pupils in Form B who had some knowledge of this principle, only one wrote the ionic equation accurately. Since only a

TABLE XLVII

Types of Error in Ions in Form A

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 310				8-10 Months No. of Pupils, 314				3-10 Months No. of Pupils, 624			
		No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals
31.	**TOTALS**	240		77.4		200		63.7		440		70.5	
	Omissions	176		56.8		85		27.1		261		41.8	
	Principle	13		4.2		13		4.1		26		4.2	
	Misc. signs only		13		4.2		12		3.8		25		4.0
	+, —		19		6.1		38		12.1		57		9.1
	Total using signs only	32		10.3		50		15.9		82		13.1	
	Numbers only	6		1.9		5		1.6		11		1.8	
	Valence	4		1.3		22		7.0		26		4.2	
	Signs reversed and Val.	1		.3		4		1.3		5		.8	
	$Na+ \quad N+ \quad NO_3-$	1		.3		0		.0		1		.2	
	Miscellaneous	4		1.3		5		1.6		9		1.4	
	$Na\,NO_3$	3		1.0		16		5.1		19		3.0	
32.	**TOTALS**	284		91.6		267		85.0		551		88.3	
	Omissions	179		57.7		86		27.4		265		42.5	
	Principle	9		2.9		24		7.6		33		5.3	
	Misc. signs only		22		7.1		40		12.7		62		9.9
	+ +, — —		8		2.6		16		5.1		24		3.8
	Total signs only	30		9.7		56		17.8		86		13.8	
	Numbers only	12		3.9		1		.3		13		2.1	
	Valence	7		2.3		20		6.4		27		4.3	
	Misc. OH		3		1.0		2		.6		5		.8
	$(OH)_2--$		11		3.5		20		6.4		31		5.0
	OH_2-		1		.3		3		1.0		4		.6
	OH —		19		6.1		38		12.1		57		9.1
	OH — —		6		1.9		10		3.2		16		2.6
	Total OH	40		12.9		73		23.2		113		18.1	
	Miscellaneous	7		2.3		7		2.2		14		2.2	
33.	**TOTALS**	309		99.7		301		95.9		610		97.8	
	Omissions	157		50.6		82		26.1		239		38.3	
	Not finished	13		4.2		11		3.5		24		3.8	
	Principle	101		32.6		111		35.4		212		34.0	
	Precipitate ionized	36		11.6		84		26.8		120		19.2	
	No ions on the right	1		.3		5		1.6		6		1.0	
	Miscellaneous	1		.3		8		[illegible]		[illegible]		1.4	

small proportion of those pupils making sign errors possess a partial knowledge of the principle of writing ions, and since only two pupils in the group could apply this knowledge accurately in the writing of the ionic equations, the possible increase in correct responses to questions 31 and 32, which would have resulted had the directions been clearly stated, would have been small indeed. The author of the tests therefore feels that this revision of directions is not going to affect the distribution of the scores or the reliability of the test. Furthermore, the diagnostic value of the test will be increased by this revision, since the chances of misunderstanding the directions will be reduced to practically zero.

In question 32, if the errors made in OH ions are considered as minor errors of principle, it is noted that that principle then occupies the most important place. Since it is possible to include all the types of error made in writing ions under the heading of principle, there is but one general type of error here. In question 33 on the writing of an ionic equation, the errors made in principle are the most significant ones. From 11.6 to 19.2 per cent of the pupils understood the general principle, but failed to appreciate the fact that precipitates do not ionize. The teacher's problem in teaching ionization lies in the teaching of the principle of writing of ions. When this topic is efficiently taught by chemistry teachers in general, the high per cents of errors due to an improper understanding of the principles will be materially reduced.

The types of error committed in *problems* really number two, that of principle and that of mechanics. In question 23 of Table XLVIII, errors in molecular weight are caused by the pupils' not knowing the principle of finding molecular weights. Strictly speaking, this item should be classified as a sub-type under "principle." The reader will also observe that the highest per cent of mechanical errors occurs in question 23. This is to be expected, since the problem requires more computations than any of the others. The errors in principle in question 23 are quite varied, while in question 24 certain sub-types, such as those in which the molecular weight is given as the answer or 22.4 liters is given as the answer, are more prominent. Where such types are dominant the teacher should not have so dif-

TABLE XLVIII

TYPES OF ERROR IN PROBLEMS IN FORM A

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 310				8-10 Months No. of Pupils, 314				3-10 Months No. of Pupils, 624			
		No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals
23.	TOTALS	235		75.3		200		63.7		435		69.7	
	Omissions	125		40.3		63		20.1		188		30.1	
	Not finished	4		1.3		5		1.6		9		1.4	
	Misc. principle		19		6.1		37		11.8		56		9.0
	Inverse proportion		4		1.3		5		1.6		9		1.4
	Total principle	23		7.4		42		13.4		65		10.4	
	Misc. mechanical		6		1.9		14		4.5		20		3.2
	Multiplication		15		4.8		20		6.4		35		5.6
	Division		12		3.9		12		3.8		24		3.8
	Total mechanical	33		10.6		46		14.7		79		12.7	
	Molecular weight	50		16.1		44		14.0		94		15.1	
24	TOTALS	261		84.2		266		84.7		527		84.5	
	Omissions	132		42.6		110		36.9		248		39.8	
	Not finished	1		.3		0		.0		1		,2	
	Misc. Prin.		68		21.9		72		22.9		140		22.4
	M. W. = Answer		25		8.1		31		9.9		56		9.0
	22.4 L = Answer		12		3.9		15		4.8		27		4.3
	.09 x M. W.		5		1.6		8		2.5		13		2.1
	M. W. x 22.4		7		2.3		10		3.2		17		2.7
	Total Prin.	117		37.7		136		43.3		253		40.6	
	Misc. mechanical		8		2.6		9		2.9		17		2.7
	Division		3		1.0		5		1.6		98		1.3
	Total mechanical	11		3.5		14		4.5		25		4.0	

TABLE XLVIII (*Continued*)

TYPES OF ERROR IN PROBLEMS IN FORM A

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 310				8-10 Months No. of Pupils, 314				3-10 Months No. of Pupils, 624			
		No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals
29.	TOTALS	250		80.7		207		65.9		457		77.3	
	Omissions	178		57.4		130		41.4		308		49.4	
	Not finished	3		1.0		2		.6		5		.8	
	Misc. Prin.		40		12.9		39		12.4		79		12.7
	L. and M. W.		17		5.5		32		10.2		49		7.8
	L.,M. W., and 22.4		8		2.6		0		.0		8		1.3
	Total Prin.	65		21.0		71		22.6		136		21.8	
	Misc. mechanical	4		1.3		4		1.3		8		1.3	
30.	TOTALS	281		90.7		276		87.9		557		89.3	
	Omissions	206		66.5		175		55.7		381		61.1	
	Misc. Prin.		32		10.3		43		13.7		75		12.0
	CO		39		12.6		52		16.6		91		14.6
	Total Prin.	71		22.9		95		30.3		166		26.6	
	Misc. mechanical	4		1.3		6		1.9		10		1.6	
38.	TOTALS	271		87.4		206		65.6		477		76.5	
	Omissions	208		67.1		115		36.6		323		51.8	
	Not finished	3		1.0		24		7.6		27		4.3	
	Misc. principle		29		9.4		38		12.1		67		10.7
	At. Wt. ÷ %		5		1.6		6		1.9		11		1.8
	% ÷ %		4		1.3		6		.3		5		.8
	% x M. W.		3		1.0		5		1.6		8		1.3
	% x At. Wt.		1		.3		4		1.3		5		.8
	CH = Ans.		5		1.6		9		2.9		14		2.2
	Total Prin.	47		15.2		63		20.1		110		17.6	
	Misc. mechanical	13		4.2		4		1.3		17		2.7	

ficult a task in applying remedial measures as those in cases in which there is a great variety in types of error without a single type's being significant. Of the mechanical errors, multiplication and division are the most important. The most significant error in principle in question 29 is the application of principles involving the use of liters and molecular weight. In the problem on Charles's Law (question 30), the most common mistake was the use of centigrade degrees as absolute temperature. In question 38, no one type of error is more prominent than another. Where the types are as varied as they are in this question, the writer infers that the lack of understanding of the principle is greater and more general than it is in those cases in which one or more types of error are prominent. In question 30, for example, among those who tried the problem, it is evident that the use of the centigrade temperatures in a proportion represents a partial understanding of the principle, since a direct proportion is used in solving the problem. In question 38, where the types are numerous, not a single type contains a principle which is partially correct.

The types of error made in problem solving indicate that this exercise is valid for diagnostic purposes, in so far as five different principles are tested.

Table XLIX shows the types of error made in multiple-choice questions. Question 34, to which the correct response is "definite proportions," shows that those pupils who do not thoroughly understand the law and its application confuse it very easily with the law of multiple proportions. Their next point of confusion is with Gay Lussac's law of volumes, which is very similar to the law of multiple proportions which treats of weights. Question 35 on the definition of a base from an ionic viewpoint, reveals the fact that pupils confuse the meanings of acids and bases. This conclusion is also verified in question 34, of Form B (Table LXXXVIII), on the definition of an acid, in which the confusion of meaning between an acid and a base again occupies first rank importance. Answer 5 in question 35 ranks next in importance, since these pupils have confused OH molecules with OH ions. Why pupils should underscore "NO_3 ions" is difficult to perceive, unless they have thought of HNO_3 as a base. The underscoring of hydrogen

TABLE XLIX

TYPES OF ERROR IN LAWS IN FORM A

No. of Ques.	Type of Error	3-6 Months No. of Pupils, 310 No. Wrong	3-6 Months % Wrong	8-10 Months No. of Pupils, 314 No. Wrong	8-10 Months % Wrong	3-10 Months No. of Pupils, 624 No. Wrong	3-10 Months % Wrong
34.	Totals	85	27.4	81	25.8	166	26.6
	Omissions	48	15.5	35	11.1	83	13 3
	1	20	6.5	24	7.6	44	7.0
	2	11	3.5	12	3.8	23	3.7
	4	1	.3	2	.6	3	.5
	5	5	1.6	8	2.5	13	2.1
35.	Totals	164	52.9	119	37 9	283	45.4
	Omissions	66	21.3	28	8.9	94	15.1
	1	60	19.4	66	21.0	126	20.2
	2	11	3.5	1	.3	12	1.9
	4	9	2.9	8	2.5	17	2.7
	5	18	5.8	16	5.1	34	5.5
36.	Totals	221	71.3	225	71.7	446	71.5
	Omissions	61	19.7	35	11.1	96	15.4
	1	65	21.0	87	27.7	152	24.4
	2	59	19.0	60	19.1	119	19.1
	4	20	6.5	28	8 9	48	7.7
	5	16	5.2	14	4.5	30	4.8
	3 and 4	0	.0	1	.3	1	.2
37.	Totals	237	76.5	216	68.8	453	72.6
	Omissions	65	21.0	40	12.7	105	16.8
	1	113	36.5	110	35.0	223	35.7
	3	4	1.3	2	.6	6	1.0
	4	13	4.2	12	3.8	25	4.0
	5	42	13.5	52	16.6	94	15.1

molecules is explainable since the pupil has confused an acid with a base and then made his choice between H ions and H molecules.

In question 36 on Charles's law, it is interesting to note that more pupils underscored "1. directly as the temperature" in preference to "5. directly as the centigrade temperature." The writer expected the greater number of pupils to underscore the latter, because its statement is the more specific and treats of the temperature usually given in problems. Number 1, then, must have been underscored the more times because it is first

in the list of answers. Answer "2. Inversely as the temperature" ranked second in importance and outranked answer "4. Inversely as to the absolute temperature." Here again is a place where one would expect these positions to be reversed, since both were inverse proportions, but the latter had an element of truth in it in the words "absolute temperature"; moreover, in problem work involving the use of this principle, pupils have been required to convert centigrade temperatures into absolute temperatures. More light will be thrown on this problem a little later in this chapter, when combinations of errors are studied. One pupil underscored two statements—the correct one and the one which directly contradicted the true statement. This was done in spite of the fact that the directions specifically stated that only one answer to each question is correct.

Question 37, an illustration of the law of conservation of matter, shows that this illustration of the law was most easily confused with the law of multiple proportions. Since the actual weights of each of the substances in the reaction were given, the pupil confused the idea of using these weights to express ratios, as they do in the law of multiple proportions, with the correct idea of thinking of the sum of the weights of the two reagents as being equal to the weight of the product. Henry's law received the least number of responses, probably because the pupil is least acquainted with it. This law, although stated in the high school chemistry texts, is not always named. The space usually devoted to this law is rather insignificant. Since the pupil knew nothing of Henry's law, and since the pupil saw none of the given elements as being common to answers 1 and 2, he took his choice between Charles and Avagadro, both of which he recognized as being familiar. Since some of these pupils knew that Charles's law treats of temperatures and volumes, they chose Avagadro's law because they knew less about it. For that reason Avagadro's law ranks next to the law of multiple proportions. Of those who had to make a choice between Charles and Avagadro, a few knew less about the former than they did the latter, and therefore underscored the former.

The types of error committed in this exercise clearly show that it is valid because pupils have confused the law or theory in question with a very similar law or theory.

7. *Combination of Errors*

In order to study the pupils' reactions to related questions, every pair of related questions in each of the 1208 papers was examined in order to record the various combinations of responses. Thus in Table L, the first seven items refer to questions 3, 4, and 5 of Part I in Form A, all of which deal with the property of weight. These seven items represent the seven different combinations of errors which the pupils can make on these questions. The table reads as follows: on oxygen, 115 pupils, or 37.1 per cent of the 310 pupils, gave wrong responses to the "Heavier than air" and the "Lighter than air," while for chlorine 41, or 13.2 per cent of the pupils, made similar responses, and so on. Of the seven items just mentioned, "heavier" and "lighter" represent the most common combination. One would expect this to be the case, for, if the pupil believes a gas such as oxygen is lighter than air, he will therefore mark both of these properties incorrectly, while the property "same weight as air" will be marked correctly. For the pupil who knows oxygen is not lighter than air, but who believes it to be the same weight as air, the incorrect marking of "heavier" and "same" will result. The pupil who marks all three items wrong is surely doing no reasoning at all, and all such responses are guesses pure and simple. Those pupils who have marked incorrectly any one of the three items have not felt sure that they knew the correct responses. Thus if a pupil did not know whether the gas is heavier or lighter than air, he knew how to mark the "same weight as air" in the right manner. If he guessed "false" for heavier, he then marked "false" for the lighter item, too, knowing that one answer was right and the other wrong. He preferred to mark them both in the same manner, rather than take a chance of having both responses wrong. The pupils' reasoning for any of the other two single wrong responses is practically the same as that which has just been presented. Apparently from the data so far presented it

TABLE L

COMBINATIONS OF ERRORS IN FORM A FOR THE 3-6 MONTH PERIOD

Part I—310 Pupils

	O_2		Cl_2		CO		A	
Property	No.	%	No.	%	No.	%	No.	%
3 and 5	115	37.1	41	13.2	175	56.4	66	21.3
3 and 4	30	9.7	4	1.3	1	.3	14	4.6
4 and 5	0	.0	2	.7	15	4.8	8	2.6
3, 4, 5	7	2.3	6	1.9	38	12.2	113	36.4
3, Heavier	4	1.3	4	1.3	4	1.3	11	3.5
5, Lighter	6	1.9	6	1.9	12	3.9	8	2.6
4, Same	1	.3	2	.7	1	.3	2	.6
6 and 7	6	1.9	19	6.1	13	4.2	5	1.6
6 and 8	3	.6	84	27.0	25	8.0	16	5.2
7 and 8	10	3.2	28	9.0	27	8.7	17	5.5
6, 7, 8	7	2.3	38	12.2	42	13.5	138	44.4
6, Supports	9	3.0	28	9.0	31	10.0	10	3.2
7. Burns	119	38.3	32	10.3	97	31.2	15	4.8
8, Exp.	17	5.4	35	11.3	30	9.7	32	10.3

Part II

30, and 36, Chas. Law	No.	%
Both Right	18	5.9
Both Wrong	210	67.6
30, Prob. Right	11	3.5
36, Law Right	71	25.8
32, 35, Ions (base)		
Both Right	19	6.1
Both Wrong	157	50.6
32, Ions Right	7	2.3
35, Def. Right	127	40.9
Def. Right, $\frac{1}{2}$ of 32	31	10.0
Both Wrong and $\frac{1}{2}$ of 32	7	2.3

would seem that the element of guessing plays rather an important part in the errors, especially in the case of argon, which has such large numbers and per cents. It must be remembered, however, that many of the responses were wrong not because the pupil guessed the wrong answer, but because he omitted the questions whose answers he did not know. This is especially true in the case of argon. If the reader will turn to Table XL he will note to what extent the omissions are responsible for wrong responses. Thus in the case of argon, the omissions range from 107 to 134, while the highest number of apparent guesses in Table L is 138. It is, therefore, observed that guessing, as far as incorrect responses are concerned, is a negligible quantity.

In items 6, 7, and 8 which treat of the related properties of supporting combustion and burning, there are again seven

TABLE LI

COMBINATIONS OF ERRORS IN FORM A FOR THE 8-10 MONTH PERIOD

Part I—314 Pupils

	O_2		Cl_2		CO		A	
Properties	No.	%	No.	%	No.	%	No.	%
3 and 5	119	37.9	35	11.1	174	55.4	88	28.0
3 and 4	27	6.6	2	.6	0	.0	24	7.6
4 and 5	1	.3	0	.0	16	5.1	3	1.0
3, 4, 5	5	1.6	10	3.2	14	4.5	67	21.3
3, Heavier	3	1.0	5	1.6	3	1.0	4	1.3
5, Lighter	12	3.8	11	3.5	6	1.9	3	1.0
4, Same	0	.0	2	.6	17	5.4	3	1.0
6 and 7	1	.3	20	6.4	15	4.8	8	2.5
6 and 8	5	1.6	123	39.2	45	14.3	18	5.7
7 and 8	10	3.2	17	5.4	28	8.9	15	4.8
6, 7, 8	8	2.5	34	10.8	31	9.9	95	30.2
6, Supports	4	1.3	43	13.7	21	6.7	6	1.9
7, Burns	100	31.8	20	6.4	97	30.8	16	5.1
8, Exp.	16	5.1	28	8.9	31	9.9	33	10.5

Part II

	No.	%
30, and 36, Chas. Law		
Both Right	21	6.7
Both Wrong	208	66.2
30, Prob. Right	17	5.4
36, Law Right	68	21.6
32 and 25, Ions (base)		
Both Right	37	11.8
Both Wrong	109	34.9
Ions Right	10	3.2
Def. Right	158	50.3
Def. Right and ½ of 32	55	17.5
Both Wrong and ½ of 32	20	6.4

possible combinations for the wrong responses. The line of reasoning followed by the pupil in these various combinations is similar to that just described for the property of weight, but there will be one difference in this case. The pupil may remember what takes place in the laboratory (question 8), but may confuse the two meanings, supporting combustion and burning. The number of pupils making the "supports combustion" and "burns in air" combination errors is rather small. This combination suggests that the pupil knew what happened in the laboratory, but confused the meanings of the two terms. In the case of the combination "supports combustion" and "experiment" the pupil had forgotten what happened in the experiment and has thought of burning and supporting combustion as the same thing. The same is true for the next

TABLE LII

COMBINATIONS OF ERRORS IN FORM A FOR THE 3-10 MONTH PERIOD

Part I—624 Pupils

Properties	O_2		Cl_2		CO		A	
	No.	%	No.	%	No.	%	No.	%
3 and 5	234	37.9	76	12.2	349	55.8	154	24.6
3 and 4	57	9.1	6	1.0	1	.2	38	6.1
4 and 5	1	.2	2	.3	31	5.0	11	1.8
3, 4, 5	12	1.9	16	2.6	52	8.3	180	28.8
3, Heavier	7	1.1	9	1.4	7	1.1	15	2.4
5, Lighter	18	2.9	17	2.7	18	2.9	11	1.8
4, Same	1	.2	4	6.4	18	2.9	5	.8
6 and 7	7	1.1	39	6.2	28	4.5	13	2.1
6 and 8	8	1.3	207	33.1	70	11.2	34	5.4
7 and 8	20	3.2	45	7.2	55	8.8	32	5.1
6, 7, 8	15	2.4	72	11.5	73	11.7	233	37.3
6, Supports	13	2.1	71	11.4	52	8.3	16	2.6
7, Burns	219	35.0	52	8.3	194	31.0	31	5.0
8, Exp.	33	5.3	63	10.0	61	9.8	65	10.4

Part II

30 and 36, Chas. Law	No.	%
Both Right	39	6.2
Both Wrong	418	67.0
30, Prob. Right	28	4.5
36, Law Right	139	22.2
32, 35, Ions (base)		
Both Right	56	9.0
Both Wrong	266	42.6
Ions Right	17	2.7
Def. Right	285	45.6
Def. Right and ½ of 32	86	13.8
Both Wrong and ½ of 32	27	4.3

combination "burning and experiment" with the difference that the pupil in this case has the right concept of supporting combustion while in the former cases the pupil had the right concept of burning. Marking all three questions wrong seems to indicate that the pupil has forgotten his experimental results on the gases and has also confused the meanings of the two terms. However, one must be on his guard in this line of reasoning since omissions hold an important place in these figures. All cases of omissions simply mean that the pupil did not know these properties. In the single responses "supports combustion" and "burns" the pupil has confused the meanings of the two terms. In the case of the wrong response on the experiment, the pupil has forgotten his experimental results.

TABLE LIII

COMBINATIONS OF ERRORS IN FORM B FOR THE 3-10 MONTH PERIOD

Part I—276 Pupils

	H_2		N_2		CO_2		He	
Properties	No.	%	No.	%	No.	%	No.	%
3 and 5	29	10.5	124	44.9	23	8.3	26	9.4
3 and 4	0	.0	2	.7	14	5.1	0	.0
4 and 5	1	.4	18	6.5	0	0.0	7	2.5
3, 4, 5	0	.0	14	5.1	17	6.1	20	7.2
3, Heavier	1	.4	8	2.9	0	.0	4	1.4
5, Lighter	1	.4	7	2.5	6	2.1	4	1.4
4, Same	1	.4	3	1.1	0	.0	2	.7
6 and 7	7	2.5	17	6.1	13	4 8	8	2.9
6 and 8	82	29.7	27	9.8	8	2.9	9	3.3
7 and 8	9	3.3	13	4.8	11	4.0	25	9.0
6, 7, 8	14	5.1	51	18.5	40	14.5	65	23.5
6, Supports	18	6.5	12	4.3	15	5.5	3	1.1
7, Burns	30	10.9	19	6.9	22	8.0	11	4.0
8, Exp.	35	12.7	30	10.9	24	8.7	48	17.4

Part II

30 and 36, Boyle's Law	No.	%
Both Right	24	8.7
Both Wrong	144	52.1
30, Prob. Right	24	8.7
36, Law Right	84	30.4
31 and 34, Ions (acid)		
Both Right	60	21.7
Both Wrong	126	45.8
31, Ions Right	22	8.0
34, Def. Right	68	24.6
28, 40		
Both Right	19	6.9
Both Wrong	199	72.1
28 Right	58	21.0
40 Right	0	.0

From the study of these combinations of errors the importance of having the pupil gain the correct concept of these terms through his first experiences in the laboratory and class is readily seen.

In Part II of the test in which two questions are related, there are four possible combinations of responses. The greatest number of pupils had both the problem and the law wrong. The problem was more difficult than Charles's law since the greater number of pupils gave the right response to the law question (36). The number answering both the problem and the law question correctly was rather small—only 18 pupils or 5.9 per cent of the group. The fact that the pupils answered

TABLE LIV

COMBINATIONS OF ERRORS IN FORM B FOR THE 8-10 MONTH PERIOD

Part I—308 Pupils

	H_2		N_2		CO_2		He	
Properties	No.	%	No.	%	No.	%	No.	%
3 and 5	16	5.2	126	41.0	34	11.0	37	12.0
3 and 4	2	.6	1	.2	9	2.9	6	1.9
4 and 5	6	1.9	22	5.1	1	.3	8	2.6
3, 4, 5	2	.6	20	6.5	20	.6	26	2.9
3, Heavier	2	.6	8	2.6	6	1.9	3	1.0
5, Lighter	5	1.6	1	.2	3	1.0	3	1.0
4, Same	3	1.0	3	1.0	1	.3	2	.6
6 and 7	16	5.2	17	5.5	20	6.5	8	2.6
6 and 8	102	33.1	26	8.4	12	3.9	12	3.9
7 and 8	14	4.5	25	8.1	13	4.2	16	5.2
6, 7, 8	22	5.1	59	19.2	41	13.3	65	21.1
6, Supports	34	11.0	13	4.2	11	2 6	9	2.9
7, Burns	25	8.1	31	10.1	22	5.1	11	2.6
8, Exp.	49	15.9	36	11.7	22	5.1	51	16.6

Part II

30 and 36, Boyle's Law	No.	%
Both Right	40	13.0
Both Wrong	155	50.4
30, Prob. Right	25	8.1
36, Law Right	88	28.6
31, 34, Ions (acid)		
Both Right	97	31.4
Both Wrong	89	28 9
31, Ions Right	31	10.1
34, Def. Right	91	29.7
28, 40		
Both Right	69	22.4
Both Wrong	153	49.7
40 Right	4	1.3
28 Right	82	26.7

the law question correctly, but failed on the problem shows their knowledge of the law was sufficient to recognize the statement of the law but insufficient for its application. This seems to indicate that such pupils did not possess sufficient knowledge to understand the meaning of the law. Had they understood the meaning they would at least have used the correct principle in solving the problem. And since Table XLVIII shows that practically all the errors occurred in principle in this problem, one can conclude that this particular group of pupils did not know the meaning of the law.

In the question on ionization, the number of pupils giving correct responses for both questions is again very small. The

TABLE LV

COMBINATIONS OF ERRORS IN FORM B FOR THE 3-10 MONTH PERIOD

Part I—584 Pupils

	H_2		N_2		CO_2		He	
Properties	No.	%	No.	%	No.	%	No.	%
3 and 5	45	7.7	250	42 8	57	9.7	63	11.0
3 and 4	2	.3	3	.5	23	3.9	6	1.0
4 and 5	7	1.2	40	6.8	1	.2	15	2.6
3, 4, 5	2	.3	34	5.8	37	6.3	46	7.8
3, Heavier	3	.5	16	2.7	6	1.0	7	1.2
5, Lighter	6	1.0	8	1.4	9	1.5	7	1.2
4, Same	4	.7	6	1.0	1	.2	4	.7
6 and 7	23	3.9	34	5.8	33	5.6	16	2.8
6 and 8	184	31.5	53	9.1	20	3.4	21	3.6
7 and 8	23	3.9	38	6.5	24	4.1	41	7.0
6, 7, 8	36	6.2	111	19.0	81	13.9	130	22.2
6, Supports	52	8.9	25	4.3	26	4.5	12	2.1
7, Burns	55	9.4	50	8.6	44	7.5	22	3.8
8, Exp.	84	14.4	66	11.3	46	7.8	99	17.3

Part II

30 and 36, Boyle's Law	No.	%
Both Right	64	11.0
Both Wrong	299	51.1
30, Prob. Right	49	8.4
36, Law Right	172	29.4
31 and 34, Ions (acid)		
Both Right	157	26.9
Both Wrong	215	36.8
31, Ions Right	53	9.1
34, Def. Right	159	27.2
28, 40		
Both Right	88	15.0
Both Wrong	352	60.3
28, Right	140	24.0
40, Right	4	.7

number giving wrong responses to both questions represents again the highest number in the group of combinations. The definition is easier than its application, as shown by the figures, 7 right for ions and 127 right for the definition. Thirty-one of the pupils answered the question on the definition correctly but wrote one of the ions for $Ca(OH)_2$ incorrectly. This indicates that the 31 pupils had a partial understanding of the application of the definition.

The trend for combinations of errors as shown in Table LI for the 8-10 month period is practically the same as that for the 3-6 month period although the numbers for combinations in

argon are materially reduced. Table LII for both testing periods brings forth no new comparisons.

Tables LIII-LV show figures for Form B which closely resemble those in Form A. The numbers for the helium combinations are much lower than they are for the argon. No further comments will be made on the data for Part I of Form B since they would be repetitions of what has gone before. However, a few observations will be made on the data on Part II because of certain differences. In the questions on Boyle's law, a higher per cent of pupils answered both questions correctly in Form B than they did in Form A. The number having both questions wrong is lower. Again the law is easier than the problem, but the contrast is not as great this time as last. The per cent of pupils answering both questions right in the case of ionization is more than three times higher in Form B than it is in Form A. The question on the writing of the ions for HCl is easier than it is for $Ca(OH)_2$ since the valence of the H and of the Cl are both one, while the calcium has a valence of two, which caused difficulty in expressing the OH radical as 2 OH ions. The ratio between the number of definitions right to the number of applications right is not as great in Form B as it is in Form A.

Questions 28 and 40 represent two equations of the same reaction, but differ in that the formulas of the reagent are given in question 28, but in question 40 the names and not the formulas of the reagents are given. The number of pupils obtaining correct responses to both questions is small, while the number of those who responded with incorrect answers to both questions is large. It is interesting to note that the 28 pupils who answered question 28 correctly failed on question 40, while none of the pupils who gave the correct response to question 40 failed on question 28. In the 8-10 month testing period 4 pupils answered question 40 correctly but failed on the easier question, number 28. Their errors in the case of the easier question are no doubt due to carelessness. The combination of the results of the two testing periods is shown in Table LV.

8. Conclusions

1. The distribution of scores in Form A for the 3-6 month testing period, although lower on the scale, is very similar to its distribution of scores in 8-10 month period as shown by Graph IV. The same is true of Form B in Graph V.

2. The distribution of scores in Form A for each of the testing periods is very similar for the corresponding periods of Form B as shown in the Graphs I-III.

3. Form A is slightly more difficult than Form B as shown by the difference of three points in median scores and as shown by a difference of seven per cent in the average per cents of correct responses for the two forms. The gas argon in Part I of Form A is responsible for the greater degree of difficulty.

4. Part I of each test is less difficult than Part II as shown by differences of 10 and 14 in the medians of the two parts of each form, and as shown by a difference of 25 and 32 per cents between the average per cents of correct responses for Parts I and II of each test.

5. When the questions of Part II in each test are classifled into seven groups, they rank in the following order from the least to the most difficult:

Form A; 1. Valence, 2. Nomenclature, 3. Laws, 4. Equations, 5. Formulas, 6. Problems, 7. Ions.

Form B; 1. Valence, 2. Equations, 3. Laws, 4. Nomenclature, 5. Formulas, 6. Problems, 7. Ions.

6. An analysis of errors in Part II of Forms A and B elicits the following conclusions:

A. The types of error occuring in Forms A and B are practically the same.

B. Those types of error which are most frequent in Form A are most frequent in Form B.

C. The type of error labeled "omissions" is present in every question and is usually the one of greatest frequency.

D. In valence, practically all the types of error are those caused by a lack of knowledge of the principle of valence. The two most frequent sub-types of error under principle are those of misplacing the subscripts and of using wrong subscripts even when the valences are given in the samples.

E. In nomenclature, all the sub-types of error recorded in tables can be attributed to the following causes: a lack of understanding of the principle of nomenclature; lack of knowledge of the fundamental formula; and a combination of both of these causes.

F. In formulas, practically all the causes for the various types and sub-types of error can be attributed to the following factors: an incomplete understanding of the principle of writing formulas; lack of knowledge or forgetfulness of the fundamental formula; lack of knowledge or forgetfulness of the valences of the elements and radicals; lack of knowledge or forgetfulness of the symbols of the elements; and various combinations of these factors such as "symbol and principle", "symbol and valence", etc.

G. In equations, the principle types of error comprise omissions, not finished, balance, formula, product, extra product, and molecular formula. In all equations for which the pupil had to write formulas, the valence error is the most frequent and the most important. This error is caused by two factors: the pupil's not knowing the principle of valence when the formulas of the regeants are given, and his not knowing the valence or the principle or both in cases in which no formulas were given. Balancing equations is a simple but important operation in writing equations, yet the frequencies for errors in balancing equations ranks higher than those for errors in products. In molecular equations, errors in molecular formulas are the most frequent, while in the writing of entire equations the writing of formulas constitutes the greatest difficulty.

H. In the ion group, all of the types and sub-types of error have been caused by the pupil's lack of knowledge of the principle of writing ions. A frequent sub-type of error occurring under principle is the writing of signs only. This has been caused by the pupil's misunderstanding the directions. When this difficulty was removed in Form X by stating the directions more clearly and concisely, this type of error became insignificant.

In the writing of the ionic equation, the principle proves to be the greatest stumbling block, while quite a number of pupils make the mistake of writing the precipitate in ionic form.

1. In problems, the errors occur in two classes: principle and mechanics. Principle by far presents the greater difficulty. In mechanics, errors in multiplication and division lead the field. These mechanical errors with the exception of the placing of the decimal point are usually careless mistakes.

J. In laws, aside from omissions, the greatest difficulty lies in the underscoring of those responses which most nearly resemble the correct responses.

7. The most significant conclusions from the teacher's viewpoint to be obtained from these data are:

A. A mastery of the valence principle on the part of the pupil is essential for the correct writing of formulas and equations.

B. The mastery of the principles of nomenclature is more important than the mere memorization of a list of commonly used formulas.

C. The importance of teaching the complete concept as a whole rather than in segregated parts is shown in the study of the combinations of errors made in these tests.

8. The conclusions regarding validity as obtained from data presented in this chapter are as follows:

A. The conditions for the administration, scoring, and analysis of the tests were uniform since the same directions were followed by all the cooperating teachers and since all papers were scored and analyzed by the writer in exactly the same manner.

B. The analysis of the errors in Part I of each test shows that the directions for Part I are responsible for keeping the guessing factor at its minimum value.

C. The results for Part I clearly show which properties are most difficult for the pupils and which gases are most difficult.

D. In Part II, all the types of error in exercises on principles of valence, nomenclature, and writing of formulas occur in those principles which each exercise is designed to test.

E. The types of error made in writing completion and entire equations show the various abilities which are required in these operations. These facts have warranted the testing of

the separate abilities and the arrangement of the more complex abilities in steps of varying degrees of complexity as has been done with the items on equations.

The types of error made at the different levels of complexity show that each step tests the ability or abilities which it was intended to test.

F. The diagnostic value of the test in numerical problems is limited to the testing of five different principles.

CHAPTER IV

A COMPARISON OF THE RESULTS OF FORMS X AND Y WITH THOSE OF FORMS A AND B

1. The Construction of Form X

During the process of analyzing the test papers, it was observed that certain types of error were caused by the arrangement and kind of statement given in the directions for certain exercises. Form X was, therefore, constructed for the purpose of discovering the effect of these minor revisions upon the results of Forms A and B. Accordingly, the specific items in their revised form, together with other items chosen from Forms A and B, were selected and arranged as a new test, called Form X.

An examination of Forms A, B, and X, which are contained in the appendix, will show to what extent minor changes were made in the questions. In questions 1-6 on the principle of valence in Form X, the directions of Forms A and B have been revised to provide for the writing of formulas in blanks in place of writing in the subscripts as was formerly done. In Forms A and B, quite a number of pupils preferred to write the complete formula after the item rather than insert subscripts in the given formulas.

By requiring the pupils to write the formulas in the blank spaces, the instructor in correcting the papers then knows whether a pupil thought the formulas correct as given or omitted them. In cases in which the given formula is already correct, the scorer is now certain of the pupil's reaction to the item. A comparison of the per cents of correct responses for each of these formulas with the per cents of the corresponding correct responses in Forms A and B will aid in determining whether these revisions have appreciably affected the results in Forms A and B.

The second change was made in the directions for the questions on writing of ions. In forms A and B, part of the

directions precedes the items while another part of them is found in the items.

Since the directions seemed to appear in two separate parts some pupils followed the directions given before the questions and paid no attention to the requirements which were set up in the questions themselves. To overcome this difficulty the complete requirements are given in the directions with nothing but the formulas and the blanks set down in the questions. A comparison of the per cents of correct responses for these items in Form X with the corresponding per cents for these items in Forms A and B will show whether the results have been materially affected or not. A further comparison of the types of error made on these items in Form X with those in Forms A and B will show whether this revision has eliminated the pupils' misunderstanding of the directions.

It will be of interest to note how the per cents of correct responses for other questions in this test compare with the corresponding per cents for Forms A and B. In this brief analysis of Form X, only the percents of correct responses and the types of error will be studied. No attempt will be made to obtain a distribution of scores and compare it with those for Forms A and B because of the dissimilarity of the two tests. Nor will there be any attempt to test the reliability of Form X since this test was constructed for the sole purpose of determining the effect of minor revision factors upon the two groups of questions.

2. A Comparison of the Per cents of Correct Responses in Form X with the Per cents of Corresponding Responses in Forms A and B

Table LVI presents the data on the numbers and per cents of pupils answering each question correctly in Form X, and the per cents for similar or same questions in Forms A and B. This table reads as follows: of the 162 pupils in this group 135, or 83.3 per cent of them answered question 1 correctly, while in Form B for a very similar question 85 per cent of the pupils answered it correctly.

All comparisons unless otherwise stated will be made with the 8-10 month group of Forms A and B since the time for giving Form X falls within this period. Parenthesis around certain per cents indicates that that question in Form A or B is not identical with the corresponding question in Form X although the two are very similar. Thus the formula in question 1, Form A is given as Na O while the formula in question 1, Form X, is given as KO. Question 8 in Form B which corresponds to question 7 in Form X reads K Cl O_4 while question 7 of Form X reads Na Cl O_4.

All the six per cents in Form X on valence correspond very closely with similar per cents for Forms A and B with the exception of 56.8 per cent for question 5 of Form X and 77.4 per cent for question 4 of Form A. The average per cent for these six questions is 67.5 while for the six similar questions in Forms A and B the average per cent is 72.3. From these comparisons, one concludes that the requirement of writing formulas in the blanks instead of writing subscripts in the given formulas will have little effect upon the distribution of scores for Forms A and B in the future.

In questions 7-10 on nomenclature in Form X, there is a fairly close resemblance in the per cents of correct responses. The naming of the formulas Na Cl O_4 and K Cl O_4 which are questions 7 of Form X and 8 of Form B respectively prove to be the most difficult items of this group, while the naming of Mg O of both tests is the least difficult question of the group.

In questions 11-14 on the writing of formulas, there are no formulas sufficiently similar in Forms A and B with which to make comparisons. Question 12 on the naming of the sodium hypochlorite formula proves to be the most difficult just as the naming of this formula in Form A proved to be the most difficult item in the nomenclature group. Mercuric oxide is apparently the easiest formula of the group to write.

A comparison of the per cents in questions 15-17 on molecular equations does not show the striking similarity one would expect. Why should question 17 produce such a low correct response as 17.9 per cent while the same question in a 308 pupil group yields 42.2 per cent of correct responses? An examination of the responses of the individual classes tested

TABLE LVI

COMPARISON OF PER CENTS OF CORRECT RESPONSES IN FORM X WITH THOSE IN FORMS A AND B

Form X No. of Pupils, 162			Form A No. of Pupils, 314		Form B No. of Pupils, 308	
No. of Ques.	No. Right	% Right	No. of Ques.	% Right	No. of Ques.	% Right
1	135	83.3	1	(85.0)*		
2	106	65.4	2	76.8		
3	118	72.8	3	75.2		
4	128	79 0			3	73.7
5	92	56.8	4	77.4		
6	77	47.5			4	45.8
7	13	8.0			8	(11.0)*
8	51	31.5			9	(44.2)*
9	124	76.5			7	63.3
10	95	58 6	9	50.0		
11	87	53.7				
12	64	39.5				
13	129	79.6				
14	83	51.8				
15	54	33.3	25	47.1		
16	48	29.6	26	33.8		
17	29	17.9			25	42.2
18	123	77.1			31	41.6
19	29	17.9			32	9.1
20	32	19.7	32	(15.0)*		
21	12	7.4	33	4.1		
22	9	5.6				
23	68	42.0			35	(43.2)*
24	43	26.5			37	27.6
25	24	14.8			40	(23.7)*

* The fact that these numbers are enclosed in parenthesis indicates that the question in Form X although very similar to the corresponding question in Form A or Form B is not identical, as in the case of those not enclosed in parenthesis.

shows the per cents in this group to be universally low. However, one class of 30 pupils brought in a very low series of correct responses for these questions and that may partially account for the differences in the responses of the groups concerned and it may also account for the very low per cent of 17.9 for question 17.

While the per cents of correct responses in writing molecular equations for Form X are uniformly below those for Forms A and B, the reverse is true in the writing of the ions. This discrepancy in the results of these two topics must be due to a difference in teaching emphasis between the three schools and the twelve schools. Then, too, the 162 pupils from three

schools may not represent as normal a sampling as 308 or 314 pupils from twelve schools. The greatest discrepancy occurs in writing the ions for HCl; the per cents are 77.1 and 41.6 respectively in Forms X and B.

The per cents of correct responses for ionic equations are the lowest for any group. The ionic equation in questions 22 is the more difficult, since it contains a compound, one of whose elements has a valence of two. Questions 18, 19, and 20 show that such compounds cause the pupils to have greater difficulty than do compounds whose elements and radicals have a valence of only one.

The per cents of correct responses on laws in Form X correspond very closely to those in Form B. The fact that iron and oxygen, instead of nitrogen and oxygen, were used in Form X had little effect upon the responses; just as in Form B the question on Gay Lussac's law has proved to be more difficult than the question on multiple proportions.

In question 25 of Form X, ammonium sulphate instead of ammonium chloride was used in the equation. The reason for the lower per cent response in Form X will be shown in the study of the types of error made in these two equations

3. A Comparison of the Types of Error Made in Form X With Those of Forms A and B.

When the errors listed in Table LVII are compared with those in Table XLIII the similarity is quite apparent. Thus in question 1 of Form X, KO_2 ranks second to omissions, while NaO_2 in Form A also ranks second to omissions. In fact, this error of misplacing subscripts occupies an important place in every one of the questions on valence. It is interesting to note the increase in errors in copying the formula without adding any subscripts. This is evident not only in question 1, but in each of the other five questions as well. This indicates that some of the omissions in valence questions in Forms A and B are not omissions but wrong responses, since some of the pupils have considered the formulas correct as they stand. The writer is therefore justified in revising the questions in valence according to the changes made in Form X, because the per cents of

TABLE LVII

TYPES OF ERROR IN VALENCE IN FORM X

Number of Pupils, 162

	No. Wrong	% Wrong		No. Wrong	% Wrong
1.	Total 27	16.7	4.	Total 34	21.0
Omissions	1	.6	Omissions	3	1.8
$K O_2$	14	8.6	Al_3PO_4	15	8.1
K O	7	4.3	$Al_2(PO_4)_2$	2	1.2
K_3O_2	2	1.2	$Al_4(PO_4)_3$	2	1.2
$K O_3$	2	1.2	$Al_3(PO_4)_3$	2	1.2
$K_3P O_4$	1	.6	10 Misc. types	10	6.2
2.	Total 56	34.6	5.	Total 70	43.2
Omissions	1	.6	Omissions	1	.6
Al N O_3	26	16.1	Mn_2O_4	19	11.7
Al_3 N O_3	16	8.7	Mn O	22	12.4
Al_2 N 0_3	3	1.8	Mn O_4	7	4.3
Al $(NO_3)_4$	2	1.2	Mn_2O	7	4.3
Al_3(N $O_3)_3$	2	1.2	Mn_4O_2	4	2.5
Al (N $O_3)_2$	2	1.2	Mn_2O_3	3	1.8
4 Misc. types	4	2.5	Mn_3O_2	2	1.2
			5 Misc. types	5	3.1
3.	Total 44	27.2			
			6.	Total 85	52.5
Omissions	1	.6			
Ca_2PO_4	17	10.5	Omissions	2	1.2
Ca_3PO_4	10	6.2	Cr_2O_6	24	14.8
Ca PO_4	3	1.8	Cr O_4	22	13.6
$Ca_2(PO_4)_3$	3	1.8	Cr O	14	8.6
Ca_4PO_4	3	1.8	Cr_6O_2	6	3.7
Ca_3PO_2	2	1.2	Cr_2O	6	3.7
5 Misc. types	5	3.1	Cr O_2	5	3.1
			6 Misc. types	6	3.7

correct responses are about equal in the revised and unrevised questions, and because the results of the revisions clearly show that some of the omissions in the unrevised tests are not omissions, but are wrong responses. Further evidence supports this argument when it is noted that per cents of error in copying the formula are increased at the expense of omissions in every question. A comparison shows that the per cents of omissions are less in valence questions in Form X than they are in Forms A and B. The only exception to this statement is the per cents of omissions for Al PO_4. In form B, there are no omissions for this question since omissions, whether they are really omissions or not, are considered as correct responses. It has been

shown earlier in this dissertation that it was possible to get an estimate as to what per cent of those counted as correct for $Al\,PO_4$ were omissions by counting the question omitted where 3 other questions on valence had been omitted in the tests (page 81). For the 8-10 month period this per cent of omissions was found to be 36 per cent, while the per cent of omissions in Form X for $Al\,PO_4$ is 1.8 per cent.

The use of subscripts taken from other than the given valences for the element and radical within the compound is also present among the Form X errors. One type of error, that of the wrong use of capitals in the symbols is entirely absent in Form X for MnO_2. Aside from the omissions, Mn_2O_4 again leads the list of errors for this question. In question 6, the error Cr_2O_6 is again the most frequent one. The types of error in this question are not as great in Form X as they are in Form B.

Table LVIII shows the types of error made in nomenclature in Form X. In 3 of the 4 questions, the highest frequency for errors occurs in writing the formulas as "ates." In two of the questions, this constitutes an error of principle only since the fundamental formula is given in the sample. The errors in naming $K_2S\,O_4$ are caused by an incomplete understanding of the principle, by not knowing the fundamental formula, or by both of these factors. The tendency in three of these questions to name the formulas "ides" is also quite strong. These same two tendencies to name compounds as "ates" and "ides" are quite strong in Forms A and B also. The reason for these tendencies, no doubt, lies in the fact that the pupil has a wider acquaintance with "ides" and "ates" in the laboratory and classroom than he does of the other salts.

The errors in question 9, the naming of MgO, are due principally to the confusion of the symbols for magnesium and manganese. This same confusion is present to a high degree in Form B. In Form B there was also the confusion of symbols for magnesium and mercury, but this confusion of symbols is entirely absent in Form X. Omissions do not play as big a part in these questions on nomenclature in Form X as they do in Forms A and B.

TABLE LVIII

TYPES OF ERROR IN NOMENCLATURE IN FORM X

No. of Pupils—162

	No. Wrong	% Wrong
7. Totals	149	92.0
Omissions	4	2.5
Sodium chlorate	82	50.6
" chloride	20	12.3
" hypo chlorite	9	5 6
" chlorite	8	5.0
" hypo chlorate	7	4.3
Not finished	5	3.1
14 Misc. types	14	8.6
8. Totals	111	68.5
Omissions	7	4.3
Potassium chlorate	37	22.8
" chloride	33	20 3
" hypo chlorite	8	4.9
" chlorous acid	5	3.1
" chlorous	5	3.1
Not finished	3	1 9
Potassium chlor.	2	1.2
11 Misc. types	11	6.8
9. Totals	38	23.5
Omissions	4	2.5
Manganese oxide	12	7.4
Maganese dioxide	8	4.9
Maganese oxide	3	1.9
Manganese dioxide	3	1.9
8 Misc. types	8	4.9
10. Totals	67	41.4
Omissions	9	5 6
Potassuim sulphate	29	17.9
" sulphide	19	11.7
" sulphuric acid	2	1.2
8 Misc. types	8	4.9

The types of error recorded in Table LIX show the same three dominant types which appear in Forms A and B. Those types are as follows: principle; not knowing the fundamental formula; and both of the aforesaid types. Errors in the symbols of the elements are again present. For questions 11 and 12, the most conspicious type of error is the writing of the formulas of the compounds as "per ates." Questions 13 and 14 contain those formulas in which there has been a confusion of symbols among the elements manganese, magnesium, and mercury. Errors in valence are also present in these two questions.

The types of error for equations are recorded in Table LX. The types of error occuring in equations in Form X are the same as those occuring in similar equations in Forms A and B. The number of types of error is not as great, however. In questions 15-17, by far the greatest numbers of errors are in writing molecular formulas, which is also true in Forms A and B. Balancing as an independent step in the writing of

TABLE LIX

TYPES OF ERROR IN FORMULAS IN FORM X

No. of Pupils, 162

	No. Wrong	% Wrong		No. Wrong	% Wrong
11.	Totals 75	46.3	13.	Totals 33	20.4
Omissions	10	6.2	Omissions	6	3.7
$HClO_4$	21	13.0	HgO_2	7	4.3
$HClO_3$	13	8.0	Hg_2O	3	1.9
HCl	11	6.8	MgO_2	3	1.9
HClO	7	4.3	MnO	2	1.2
ClO_2	4	2.5	MgO	2	1.2
HCl_2	2	1.2	Hg_2O_2	2	1.2
Misc. types	7	4.3	8 Misc. types	8	4.9
12.	Totals 98	60.5	14.	Totals 79	48.2
Omissions	6	3.7	Omissions	6	3.7
Not finished	15	9.2	Mg S	15	9.2
$NaClO_4$	10	6.2	Mn_2S	6	3.7
$NaClO_2$	9	5.6	$MgSO_4$	6	3.7
NaHClO	9	5.6	$MnSO_2$	5	3.1
$NaHClO_3$	6	3.7	$MnSO_3$	5	3.1
$NaHClO_2$	6	3.7	Mn_2S_3	4	2.5
$NaClO_3$	6	3.7	$MgSO_3$	4	2.5
$NaHClO_4$	5	3.1	$MgSO_2$	2	1.2
$NaCl_3O_3$	4	2.5	26 Misc. types	26	16.0
NaCl	3	1.9			
$NaH(ClO_2)_2$	2	1.2			
Na_2Cl	2	1.2			
SO_4	2	1.2			
13 Misc. types	13	8.0			

molecular equations has caused considerable difficulty in question 16, but not in the other 2 molecular equations. It caused a like result in Forms A and B. Why this equation should be so much harder to balance than the others is hard to determine since the process of balancing in this equation is the same as in the other 2 equations. The fact that Na has one atom to the molecule instead of two as have the elements in the other two equations should not make the balancing process more difficult.

In question 25, aside from omissions, not knowing the formula caused the greatest difficulty. The fact that the per cent of errors in formula is twice as high in Form X as it is in Form B suggests that the ammonium sulphate instead of am-

TABLE LX

TYPES OF ERROR IN EQUATIONS AND LAWS IN FORM X

No. of Pupils—162

Equations	No. Wrong	% Wrong		No. Wrong	% Wrong
15. Totals	108	66.7	25. Totals	138	85.2
Omissions	14	8.6	Omissions	64	39.5
Mol. H	11	6.8	Not Finished	11	6.8
" O	14	8.6	Formula	40	24.7
" H & O	60	37.0	Valence	8	4.9
Balance	9	5.6	Balance	8	4.9
			Product	7	4.3
			Laws		
16. Totals	114	70.4	23. Totals	94	58.0
Omissions	42	26.0	Omissions	14	8.6
Mol. Na	1	.6	1	4	2.5
Mol. H	40	24.7	3	55	33.9
Balance	29	17.9	4	12	7.4
Formula	1	.6	5	9	5.6
Product	1	.6			
17. Totals	133	82.1	24. Totals	119	73.5
Omissions	41	25.3	Omissions	13	8.0
Mol. N	42	26 0	1	66	40.7
" N & O	41	25.3	3	30	18.5
Balance	3	1.9	4	10	6.2
Formula	6	3.7	5	0	.0

monium chloride in the equation has made the equation more difficult. A re-examination of the errors made in formulas in question 40 reveals the fact that 1.3 per cent of the pupils made errors in the formula NH_4Cl in Form B while 6.1 per cent of the pupils committed errors in the formula for $(NH_4)_2SO_4$ in Form X. In Form B in the Ca $(OH)_2$ formula, 5.5 per cent made errors while in Form X in the Ca $(OH)_2$ formula, 7.4 per cent made errors.

In the two questions on laws, the ranks of frequency for the types of error is the same in Forms X and B. In Form X, there are no cases where two answers are underscored as in Form B. The confusion of Gay Lussac's law with the law of definite proportions is just as prominent in Form X as in Form B.

TABLE LXI

TYPES OF ERROR IN IONS IN FORM X
No. of Pupils—162

Ionic Formulas	No. Wrong	% Wrong	Ionic Equations	No. Wrong	% Wrong
18. Totals	39	22.9	21. Totals	150	92.6
Omissions	23	14.2	Omissions	5	3.1
Valence	5	3.1	Not finishd	1	.6
Signs only	2	1.2	Principle	75	46.3
Numbers and signs	1	.6	Precipitate	42	25.9
Symbols and numbers	1	.6	Same on both sides	2	1.2
" only	1	.6	No ions on right	6	3.7
Names and signs	3	1.9	Valence	2	1.2
3 Misc. types	3	1.9	No ions on left	17	10.5
19. Totals	133	82.1	22. Totals	153	94.4
Omissions	26	16.0	Omissions	13	8.0
Principle	87	53.7	Not finished	4	2.5
Valence	9	5.6	Principle	73	45.1
Signs only	1	.6	H_2O	37	22.8
Numbers only	1	.6	Same on both sides	1	.6
Symbol "	1	.6	2Cl	1	.6
8 Misc. types	8	4.9	No ions on right	5	3.1
			No ions on left	14	8.6
20. Totals	130	80.3	OH—	1	.6
			2 Cl_2—	1	.6
Omissions	26	16.0	H Cl	1	.6
Principle	98	60.5	Cl_2	1	.6
Valence	4	2.5	Product	1	.6
Numbers and signs	1	.6			
Signs only	1	.6			

The types of error made in ions are shown in Table LXI. As in the case of Forms A and B all the errors can be classified under principle. The number of types of error in Form X is not as great as that in Forms A and B. The significant difference in the results is that errors in "signs only" occupy a very subordinate place in Form X while in Forms A and B they occupied an important place. The revision of the directions has certainly greatly reduced this type of error. Even though the similarity between the two per cents of the Form X questions and those of Forms A and B is not quite as exact as is desired, yet this change is justified in the light of the results of the revision.

Those compounds such as $Na_2 S O_4$ and Ca $(N O_3)_2$ which have more than two ions cause much greater difficulty than

those which have only two ions such as H Cl or $NaNO_3$. The difficulty does not lie so much in the writing of the ion of the bivalent element as it does in writing the univalent radical as two ions. Valence plays a minor roll in these questions, but a rather important one. This point only tends to verify the one which has already been made regarding the importance of the pupil's knowing the valences of the common elements and radicals if he is to write the formulas, equations, ions, and ionic equations correctly.

The types of error committed in the writing of ionic equations follow very closely those committed in Forms A and B. Practically all of them can be listed under the heading of principle. In question 21, pupils made the mistake of ionizing the precipitate, while in question 22 they made a similiar error in ionizing the product water. The per cents of omissions are low for these two questions when compared with similar per cents in Forms A and B.

4. The Construction and Use of Form Y

It has been the purpose of this investigation to construct a diagnostic test in the mechanics and the directly related fundamentals of high school chemistry. During the process of analysis, it has been shown that one item, the question on the law of multiple proportions, is not directly related to the specific type of numerical problem of computing a simple formula which was finally selected for the test. It was therefore thought desirable to select an item which would be more closely related to specific items in the test. Since it has been shown that the principle of valence occupies an important place in the mechanics of chemistry, an item on the theory of valence has been selected to take the place of the item on the law of multiple proportions.

In the discussion of the textbook analysis, it was shown that problems in percentage composition rank fourth in importance from the standpoint of space occupied in the texts and College Board examinations.[42] A statement was made that the per-

[42] See Table XVII.

TABLE LXII

Form Y

*Number and Per Cent of Pupils Answering Each Question Correctly

No. of Question	No. Right	Per Cent Right
1	71	27.2
2	42	16.0
3	133	50.8
4	139	53.1
5	125	47.7
6	89	34.0

*No. of Pupils—262

TABLE LXIII

Types of Error in Laws and Theories

Form Y— Number of Pupils 262 Form B Number of Pupils 308

No. of Question	Types of Error	No. Wrong	Per Cent Wrong	No. of Question	Types of Error	No. Wrong	Per Cent Wrong
1. Totals		191	72.8				
Omissions		2	.8	37 Totals		223	72.4
	1	117	44.6	Omissions		38	12.3
	3	60	22.9		1	125	40.6
	4	12	4 6		3	46	14.9
	5	0	.0		4	14	4 5
					5	0	.0
2. Totals		220	84.0				
Omissions		6	2.3				
	1	35	13.4				
	2	9	3.4				
	3	94	35.9				
	5	76	29.0				

centage composition type of problem was not selected because of its principle being present in the type of problem involving the computation of a formula. In this particular problem in the test, the percentage composition is given for the computation of the formula. This problem does not, therefore, test the pupil's ability to calculate percentage composition. Since the authors of both chemistry texts and College Board deem this an important type of problem and since the same principle operates in the per cent type of problem, which ranks sixth,[42] it was thought best to include this type of problem in the tests. A short test has, therefore, been devised to include these two types of material.

42 See Table XVII.

TABLE LXIV

TYPES OF ERROR IN PROBLEMS IN FORM Y

Number of Pupils—262

No. of Question	Type of Error	No. Wrong	Sub-Totals	Per Cent Wrong	Per Cent Sub-Totals
3.	Totals	129		49.2	
	Omissions	27		10.3	
	Not finished	3		1.1	
	Principle	85		32.4	
	29 x Wt. of 1 liter		21		8.0
	Wt. of 1 liter ÷ 29		6		2.3
	Wt. of 1 liter ÷ 22.4		12		4.6
	Wt. of 1 liter = ans.		1		.4
	Wt. of 1 liter = ans.		1		.4
	22.4 ÷ Wt. of 1 L.		12		4.6
	32 x Wt. of 1 L.		1		.4
	32 ÷ Wt. of 1 L.		1		.4
	Wt. of 1 L. ÷ .09		8		3.1
	Miscellany		22		8.4
	Mechanics	14		5.4	
	Multiplication		13		5.0
	Decimals		1		.4
4.	Totals	123		46.9	
	Omissions	34		13.0	
	Not finished	2		.8	
	Principle	76		29.0	
	Wt. of 1 L. ÷ .09		8		3.1
	22.4 ÷ Wt. of 1 L.		21		8.0
	Wt. of 1 L. ÷ 22.4		9		3.4
	22.4 = ans.		1		.4
	29 x Wt. of 1 L.		15		5.7
	Wt. of 1 L. ÷ 29		9		3.4
	Wt of 1 L. = ans.		1		.4
	32 x Wt. of 1 liter		1		.4
	32 ÷ Wt. of 1 L.		1		.4
	Miscellany		10		3.7
	Mechanics	11		4.2	
	Multiplication		6		2.3
	Decimals		4		1.5
	Copying		1		.4
5.	Totals	137		52.3	
	Omissions	12		4.6	
	Not finished	14		5.4	
	Principle	88		33.6	
	M. W. ÷ M. W. of 5 H_2O		14		5.4
	M. W. ÷ M. W. of H_2O		1		.4
	M. W. of 5 H_2O ÷ M. W. of $CaSO_4$		4		1.5
	Molecular weight		33		12.6
	Miscellany		36		13.8

TABLE LXIV — Continued

FORM Y

TYPES OF ERROR IN PROBLEMS

Number of Pupils — 262

No. of Question	Type of Error	No. Wrong	Sub-Totals	Per Cent Wrong	Per Cent Sub-Totals
	Mechanics	23		8.8	
	Addition		7		2.7
	Division		9		3.4
	Multiplication		5		1.9
	Decimals		2		.8
6	Totals	173		66.0	
	Omissions	22		8.4	
	Not finished	12		4.6	
	Principle	115		44.0	
	M.W. ÷ Wt. of Na_2		16		6.1
	M.W. of $10H_2O$ ÷ M.W.		4		1.5
	At. Wt. of Na. ÷ M.W.		1		.4
	Wt. of Na_2 ÷ M.W. of Na_2CO_3		6		2.3
	M.W. of Na_2CO_3 ÷ M.W.		8		3.1
	M.W. ÷ M.W. of Na_2CO_3		2		.8
	Molecular weight		45		17.2
	Miscellany		33		12.6
	Mechanics	24		9.2	
	Addition		5		1.9
	Division		13		5.0
	Multiplication		2		.8
	Decimals		3		1.1
	Copying		1		.4

This test was tried out in four public high schools, two of which are located in Philadelphia, one in the suburbs of Philadelphia, and the fourth in Western New Jersey. In all, 262 pupils took the test during the latter part of March, 1931.

These tests were scored and analyzed by the writer in the same manner as was Form X. The results of the analysis are shown in Tables LXII-LXIV. Table LXII shows that question 1 on Gay Lussac's law was answered correctly by 27.2 per cent of the 262 pupils, while the same question was answered correctly by 27.3 per cent of the 308 pupils who took Form B during the 8-10 month period.[43] Not only are the per cents of correct

43 See Table XXX.

responses almost equal but the per cents of types of error are approximately equal, with the exception of omissions. If the results on this one question are any indication of the similarity of abilities of the two groups, the results on the remaining questions in Form Y should provide per cents of correct responses which would compare favorably with those of the 308 pupil group, had that group been tested on the Form Y questions.

The per cent of correct responses for question 2 on the theory of valence is low at 16 per cent. The textbook used by three of the five teachers who gave the test contains a discussion of valence and devotes space in several chapters to the construction of atoms of certain elements. Since the theory of valence is actually a part of the electron theory, the analysis of the six representative textbooks shows that the theory of valence is discussed in all six texts, but not always under the heading of theory of valence.[44] Moreover, the direct relationship of the theory of valence to the principle of valence justifies the using of this item in the final form of the diagnostic tests, although it is apparently an exceedingly difficult question. The fact that types of error are so well distributed among three of the four wrong responses, is an indication that these pupils have very hazy ideas regarding the meaning of the terms proton and electron and their relationship to the cause of valence. If the cause of valence is being taught in the schools, then this question performs a diagnostic function.

Questions 2 and 3 on finding the molecular weight of a gas when the weight of a liter is given, are much less difficult for this group of pupils than the reverse process was for pupils who were tested by Forms A and B. In computing the weight of one liter of gas, 15.8 per cent and 13 per cent of the pupils during the 8-10 month period answered this type of question correctly in Forms A and B respectively. It is interesting to note that the types of error committed on this type of problem in Form Y are just the reverse of those committed by pupils in Forms A and B. For example, the weight of a liter divided by 22.4 in question 3 of Form Y is the opposite to 22.4 times molecular

44 See Table XV.

weight in question 24 of Forms A and B.[45] A new type of error, "29 x Wt. of 1 liter" appears in questions 3 and 4. The pupils have confused the principle of this problem with that of finding molecular weight when the specific gravity of the gas referred to air is given. The per cents of mechanical errors, 5.4 and 4.2, in questions 3 and 4 correspond rather closely to those in Forms A and B at 4.5 and 4.9 per cents respectively.

Questions 5 and 6 on the percentage composition type of problem vary in difficulty since 47.7 per cent of the group answered question 5 correctly, while 34 per cent of the group gave the correct response for question 6. The most important type of error in principle is the violation of the principle of finding molecular weight. The main difficulty here was finding that portion of the molecular weight which concerned the molecules of water of crystallization. The second important type of error is the dividing of the molecular weight by the weight of the constituent whose per cent is to be determined. In question 6, 4.6 per cent of the pupils found the per cent for the wrong constituents (M. W. of 10 H_2O ÷ M. W. and M. W. of Na_2CO_3 ÷ M. W.) The per cents of mechanical errors such as addition, division, et cetera are rather high.

The percentage composition type of problem measures three abilities: the ability to apply the principle of percentage composition; the ability to apply the principle of computing the molecular weight; and the ability to make accurate calculations. This type of problem should be placed in the final forms of the test for these reasons: the percentage composition problem ranks fourth among the problems in six representative textbooks; its principle is involved in other types of problems such as the equation and per cent types; it involves the use of the principle of molecular weights, which is used in equation problems and the computation of the weight of a liter of gas; and it is valid for diagnosis as shown by the types of error in principle and mechanics.

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45 See Tables XLVIII and LXXXVII.

5. Conclusions

1. The proposed revisions for the questions on valence and ionization in Forms A and B as tried out in Form X will have little or no effect on the distribution of the scores of these tests and their reliability in future use and they will increase the diagnostic value of Forms A and B for the following reasons:

A. The per cents of correct responses for the valence question in Form X are approximately equal to the per cents of correct responses of the same or very similar questions in Forms A and B.

B. The per cents of correct responses for the ion questions in Form X, although they show a wide discrepancy of 35.5 per cent in one question when compared with per cents of similar questions in Forms A and B are not sufficiently divergent to cause any appreciable change in the distribution of the scores. Of those pupils in Forms A and B who misunderstood the directions, from one fourth to one half of them showed a partial knowledge of the ionization principle when they attempted to write the ionic equations, and of those pupils who made this type of error only 2 pupils succeeded in writing the correct ionic equations.

C. An analysis of the errors in valence shows that the diagnostic value of the valence questions has been increased, for it is now possible to determine which questions the pupil has omitted and which ones he has considered as correct. Furthermore, the revision will increase the accuracy of scoring question 3 of Form B since omissions will no longer be marked as correct responses.

D. An analysis of the errors in writing ions likewise shows that the revision of directions has increased the diagnostic function of this group of questions by practically eliminating the possibility of the directions being misunderstood as they were in the unrevised form.

2. An analysis of the remaining groups of questions in Form X on nomenclature, formulas, equations, and laws yields the same conclusions for these groups as those given at the close of Chapter III.

3. The substitution of the theory of valence item for the law of multiple proportions question is justifiable on the following grounds:

A. The relationship of the theory of valence to the principle of valence is much stronger and more direct than is the relationship between the law of multiple proportions and the problem which involves the computation of one formula.

B. The distribution of the types of error on the theory of valence in Form Y shows that the item is valid from the diagnostic standpoint.

4. The inclusion of the percentage composition type of problem in the final forms of the test is justified for the following reasons:

A. Textbook analysis reveals that it ranks fourth in importance among problems from the standpoint of per cent of total space devoted to it in textbooks.

B. This percentage principle also occurs in certain subtypes of equation problems and in per cent problems.

C. This type of problem involves the use of the principle of molecular weights, which is used in the other types of problem.

D. This type of problem also measures the ability to do accurate work as shown by the errors made in mechanics.

E. The problem is diagnostic since practically all the types of error fall under the headings "principle" and "mechanics."

CHAPTER V

VALUE AND USES OF THE DIAGNOSTIC TESTS

1. For Diagnosing Pupils' Difficulties in the Mechanics and Related Fundamentals of High School Chemistry

It has already been stated in the first chapter that the purpose of this investigation is to construct a diagnostic test in the mechanics of chemistry and its directly related fundamentals. Previous discussions have shown that the materials comprising the test are purely of a mechanical and fundamental nature and that they have been so organized as to perform the diagnostic function. It now becomes the purpose of this investigation to indicate the value of these tests in diagnosing pupils' difficulties in the mechanical and fundamental operations in high school chemistry, in the application of remedial measures, and in the refinement of teaching procedures.

Since the chemistry teacher may not have the time or the desire to enter upon as detailed an analysis as has been employed in this thesis, the writer proposes a simpler and easier method of analysis which he has designated as "diagnostic scoring." This method of diagnostic scoring was used by the writer in reporting the results of the tests to the cooperating teachers. Table LXV is a copy of one of the data sheets which was returned to one of the cooperating schools. In this table the names of the pupils have been omitted. Table LXVI represents a simple analysis of the scores of twenty pupils for Part I, Form A.

Table LXV is read as follows: In Form A, pupil 1 made a score of 28 in Part I, 4 in Part II, giving a total score of 32. In Part II, pupil 1 scored one on the five valence questions; zero in the six questions on nomenclature; zero in the six questions on writing formulas; 3 on the three questions on balancing of equations; zero on the two double decomposition equations; zero on the two molecular equations; zero on the four completion equations; zero on the three questions on ions; zero on the

TABLE LXV

DIAGNOSTIC SCORES OF PART II, FORM A

Pupils	Part I	Part II	Total	Valence 1-5	Equations: Names 6-11	Formulas 12-17	Balance 18-20	Comp. D.D. 21-22	Comp. Mol. 25-26	Comp. 27, 28 39, 40	Ions 31-33	Laws 34-37	Probs. 23, 24, 29 30, 38
1	28	4	32	1	0	0	3	0	0	0	0	0	0
2	29	21	50	4	4	3	3	0	0	1	0	3	3
3	34	25	59	4	3	3	3	2	0	4	2	3	1
4	26	19	45	4	3	1	3	0	0	2	1	3	2
5	35	25	60	5	5	4	3	1	2	3	0	2	0
6	31	12	43	4	2	1	1	0	0	0	1	2	1
7	30	22	52	4	4	4	3	1	2	1	0	3	0
8	35	15	50	4	2	1	3	1	0	2	0	2	0
9	27	13	40	2	2	2	3	0	1	1	0	2	0
10	37	17	54	5	2	2	1	0	1	1	2	2	1
11	33	17	50	2	3	2	2	1	2	1	0	3	1
12	35	22	57	3	4	3	3	2	2	0	2	3	0
13	34	24	58	5	4	3	2	2	2	1	2	3	0
14	31	8	39	1	1	1	3	0	1	0	0	0	1
15	28	22	50	4	4	4	3	0	2	2	0	2	1
16	31	18	49	2	4	2	3	1	0	2	0	2	2
17	30	29	59	4	6	4	3	1	2	3	2	2	2
18	30	23	53	5	4	3	3	1	2	2	0	3	1
19	31	23	54	5	4	3	3	1	2	0	1	4	0
20	34	27	61	5	4	4	3	1	2	2	2	4	0
21	33	25	58	4	3	4	3	2	2	2	0	4	1
22	32	11	43	1	2	2	2	0	0	2	0	2	0
23	37	19	56	2	3	3	3	1	2	2	0	3	0
24	37	21	58	3	5	3	2	0	0	3	0	3	2
25	29	23	52	5	4	4	3	1	0	2	0	3	1
26	29	25	54	4	4	3	3	1	2	4	2	2	0
27	36	23	59	4	4	4	3	1	2	2	1	2	0
28	32	26	58	5	3	5	2	2	2	1	2	3	1
29	35	21	56	4	4	3	3	0	1	3	0	1	2
Totals				105	97	81	78	23	34	49	20	72	23
Average % correct				72.4	55.7	46.5	89.3	39.5	58.5	42.0	22.7	65.0	15.8

four questions on laws; and zero on the five problems. The total scores for Part II are recorded at the bottom of the page. The per cents these totals are of the totals of perfect scores are recorded under the totals as "average per cent correct." Thus, 72.4 per cent of the responses of the class to the valence questions are right responses.

This analysis of the scores of Part II of Form A becomes at once useful to the teacher of this class of 29 pupils in diagnosing the difficulties of the class as a whole and in diagnosing the difficulties of individual pupils. A glance at the per cent

TABLE LXVI

DIAGNOSTIC SCORES OF PART I, FORM A

	Gases				Properties									
Pupils	O_2	Cl_2	CO	A	1	2	3	4	5	6	7	8	9	10
1	8	7	4	8	3	3	2	4	2	3	2	3	1	4
2	9	8	7	8	4	4	1	4	1	4	3	4	4	3
3	10	7	7	0	3	3	2	3	2	2	3	1	3	2
4	8	7	4	7	3	3	1	3	2	2	4	1	3	4
5	10	8	8	10	4	4	3	4	3	4	3	4	3	4
6	8	6	7	6	2	4	1	3	2	3	3	3	2	4
7	6	8	9	8	4	4	3	4	3	2	2	4	2	3
8	7	7	5	9	3	4	2	4	1	3	3	3	2	3
9	9	7	6	10	4	3	3	4	3	3	3	3	2	4
10	8	7	7	8	4	2	3	4	3	3	3	3	1	4
11	7	8	6	3	4	4	0	4	1	2	2	3	1	3
12	9	4	8	8	2	2	2	4	2	4	3	3	3	4
13	10	8	8	5	3	3	3	4	3	3	3	2	3	4
14	10	10	8	8	4	4	2	4	2	4	4	4	4	4
15	7	8	6	8	4	4	2	4	2	2	3	3	2	3
16	10	6	8	8	4	3	2	4	2	3	3	3	4	4
17	9	8	8	10	4	3	4	4	3	2	4	3	4	4
18	7	7	7	8	3	3	3	4	3	3	2	2	2	4
19	10	9	6	10	4	4	3	4	3	3	4	2	4	4
20	3	4	6	0	2	3	1	2	0	2	2	3	1	2
Totals	171	144	135	142	68	67	43	75	43	57	59	57	52	71
Av. % Correct	85.5	72.0	67.5	71.0	85.0	83.8	53.8	93.8	53.8	71.3	73.8	71.3	65.0	88.8

figures immediately shows this teacher that problems are causing his pupils the greatest difficulty, with ions as a close second. Among the different types of equations, the balancing operation has proven the least difficult, while the double decomposition and completion equations possess a higher degree of difficulty. His class has a fair understanding of the principle of valence, but fails to measure up to the requirements in writing formulas in which one of the principles used is that of valence. This teacher should also note that the application of the principles of nomenclature proves easier for his class than does the application of those in formula writing. These observations concerning his class as a whole should be the basis for determining what remedial procedures he will now employ for the class. These will be discussed later under the heading of remedial measures.

If he feels that this class diagnosis is not sufficient he should then find the number of pupils making correct responses to each

item. With those data he can then determine which types of problems are the least difficult and which ones are most difficult. He can find out the same type of facts in the other groups of questions as well. By so doing, he can concentrate his remedial measures within each group rather than spread them over the whole group of questions.

After having taken care of the class as a whole, he is now in a position to make a study of the individual cases. From a scrutiny of the individual scores, he will note that three pupils in his class are in dire need of his help. Those pupils are numbers 1, 14, and 22. These three pupils are weak in every one of the operations with the exception of balancing equations. These pupils then must be given individual assistance. He should select for special aid or drill those who have made a score of two or less in valence, those who have scored less than four in nomenclature, in formulas, etc. If certain of these weaknesses are taken up by the class, it will not be necessary for the teacher to render individual assistance in many of the cases.

Table LXVI presents the analysis for Part I of Form A and is read in the following manner: Pupil 1 scores 8 out of a possible 10 for O_2, 7 out of a possible 10 for Cl_2, 4 out of a possible 10 for CO, 8 out of a possible 10 for A, 3 out of 4 for property 1 ("colorless"), 3 out of 4 for property 2, 2 out of 4 for property 3, and so on. The total scores for the columns are given at the bottom of the columns. When these totals are divided by the total perfect score, the average per cent of correct responses for each column is found. By observing the average per cents of correct responses at the foot of each column, the instructor can easily perceive which gases and which properties were the most difficult. For this group of gases, CO proved to be more difficult than argon. Among the properties, 3 and 5, on the weight of the gases, have proved to be the most difficult, while property 4, "the same weight as air" and property 10 on bleaching, have been the least difficult.

Since Part I is much less difficult than Part II, and since the subject matter in it is so vastly different from that in Part I, the teacher can take care of both individual and class difficulties through remedial measures which involve the class as a whole.

If individual work is necessary, it can be assigned to the individual pupils, but the individual assistance and drill which is required in Part II will not be necessary in Part I.

Usually for diagnostic purposes, the chemistry teacher will not have to go beyond the two steps which are presented in this chapter, namely, diagnostic scoring of Parts I and II and the finding of the number and per cent of pupils answering each question correctly. There may be classes in which only the diagnostic scoring is essential; there may be groups which require both steps; and finally some instructors may find it necessary to perform still other steps. Thus in Table LXV, pupils 1, 14, and 22 may require added measures to remedy their difficulties. The intelligence quotients and their abilities to read may have to be obtained before proceeding further with their remedial measures in chemistry. Again the teacher may not be quite satisfied with the analysis thus far completed, and may feel that he needs to know more about the results of this test if he is to modify his teaching methods. If such is the case, it will be necessary for him to analyze the types of error made by his pupils in Part II. By knowing the types of error present in the test, he can so modify his teaching as to prevent or greatly reduce these types of error in the future.

2. *For Proposing Remedial Measures*

Now that the instructor has diagnosed the difficulties of his class by means of diagnostic scoring and the per cents of correct responses, it is possible to determine remedial measures to follow up the result of his diagnostic study.

After the teacher has completed this analysis he may want to devote two or three class periods to remedial measures, or he may prefer to use just a portion of each class period for a couple of weeks to such measures, so as not to overload his class with remedial processes to the extent that the whole task becomes more or less distasteful to them. In the allotment of time to the various types of difficulties, he will spend the least amount of time on the easiest groups, such as valence, for example, and he will devote the greatest portions of time to those groups which have been especially difficult, such as problems and ions. For example, in the topic of valence he will explain

to the class very briefly the principle of valence, using a few illustrations to make his points clear. Since question 5 of this group was the most difficult question, he will have the class work out two or more questions of this particular type with him. By asking specific questions on this item, the teacher will reveal to the pupils their difficulties and thus clarify their thinking. His next lesson assignment will include exercises on the topic of valence.

During the period he will reteach the subject of nomenclature and formula writing. In presenting these topics, he will stress the principle of naming and writing the formulas and the necessity of knowing the fundamental formula. He must arouse in the class the desire to apply the principles of nomenclature and formula writing, rather than try to burden their memories with every name and formula with which they come in contact. The pupils will then be given opportunities in class to name and write formulas. When the teacher feels that these principles are understood by the class, he will assign as part of the home work, exercises in the naming and writing of formulas. At the beginning of the next class period, the teacher will have the pupils read and correct their home work on valence, nomenclature, and formulas. From a personal examination of these papers, he will select those pupils who still need individual attention.

During this second class period, he will devote a portion of the period to the subject of equations. To the process of balancing equations not more than two minutes should be necessary, since there are not less than two pupils and not more than seven in the class who do not know how to balance equations. These two minutes are necessary, since these seven pupils must understand how to balance equations in the types which will be explained next. In the double decomposition equations, the teacher should stress the fact that in such equations the elements or radicals exchange places. This should be emphasized by means of several illustrations supplied by the class and by the teacher. He should then point out to the pupils that the matter of valence should not be a disturbing factor, since the formulas of the reagents are given, and if they know how to apply the principle of valence to the determination of the val-

ences of the radicals or elements, there should be no difficulty in writing the formulas of the products. If he finds that the class at this point is experiencing difficulty in the determination of valences, he had better take time to have them practice designating valences from given formulas. He should spend a little of the class time in having the pupils practice writing equations of this type. If his allotted time for remedial measures during this class period has expired, he will assign a few exercises in balancing equations and quite a number in the writing of double decomposition equations.

During a portion of the next class period, the instructor will explain and illustrate the method of writing molecular equations. Pains will be taken to stress the fact that elements in the gaseous state usually have two atoms per molecule, while elements in the solid state, or those gaseous elements like argon or helium, which are inert, usually have but one atom to the molecule. Furthermore, it should be pointed out that the formulas for compounds are already in the molecular form and, therefore, need no changing. Practice should then be given in the writing of equations with gaseous and solid elements in them.

The principal factor to be stressed in the reteaching of completion equations is knowing the products and setting down their formulas in the equation before attempting to balance the equation. This should always be the case, no matter what the type of equation. When pupils use another order in their procedure, they frequently change the formulas of products or add extra products in order to make the equation balance. In the case of those completion equations in which no formulas are given for the reagents, the pupil must know the formula for the reagent before he can start writing the equations. The steps in the procedure of writing these equations should include all the separate steps which have been presented for the preceding types. The teacher in making his home work assignment on completion equations should select only those reactions with which the pupil has become acquainted in the laboratory and class. This is necessary, because the pupil has to know the products of the reaction, or he has to know where he can find them if he is to be able to write the equation.

In the reteaching of ions and laws, more time will need to be spent on the theory of ionization than upon laws. Reading assignments both in the text book and reference material on the theory of ionization should be made. Exercises should be assigned in which the pupil will have ample opportunity to write compounds as ions and to write ionic equations. Review assignments on the reading material given in the texts should be assigned in preparation for the reteaching of the laws. Part of the assignment should consist in having the pupils prepare lists of applications and illustrations of the laws. Where the per cents of correct responses to the separate law questions have shown certain laws to be more difficult than others, the teacher should require a longer list of applications and illustrations. The meanings of the laws, their illustrations, and applications should then be discussed in class.

In the case of remedial work in problems, the per cents of correct responses will aid the teacher in placing the teaching emphasis on those types which are most in need of emphasis. During the first time he presents this material for reteaching, the instructor should present, explain and illustrate about two types of these questions. In the case of the equation problem which involves the use of atomic weights and actual weights and which has been the least difficult for the class, the teacher will insist upon the pupils' knowing the principles which are involved in the various operations and upon accuracy in the calculations. To insure accuracy, he should inform the class that in the future, errors in accuracy will cause greater reduction in grades than formerly. For example, if the teacher has only cut the grade on a paper slightly for problems in which the principle was correct but the calculations incorrect, he will now count principle one half and accuracy one half. The homework assignment will contain problems of the types which have been presented in class. Even after all the types of problem have been presented in class and solved in the pupils' homework, the teacher will find it necessary to require as homework a few of these problems from week to week.

If the teacher has made a study of the types of error made by his pupils in the case of problems, he will note that errors in principle are caused by a partial understanding of the principle.

For example, in questions on finding the weight of one liter of a gas, the pupil will find the molecular weight and call the final answer to the first step of the operation the answer. Or, if he uses the 22.4 liters method he will call 22.4 liters the answer. At other times the pupil will use correct procedures for certain steps in the process and then use wrong principles in other steps of computation. When the teacher knows these facts he can show clearly the principles involved in each step, and make sure that the pupils thoroughly understand them and know how to apply them. He will show his pupils just why their answers were wrong in the test. When the pupil sees and understands the correct method and the reason that his problem was wrong, he will then improve his ability in solving problems.

In the reteaching of the properties of gases to the class as a whole, this teacher will do well in putting on a demonstration experiment on carbon-monoxide, since the properties of this gas proved most difficult for his class. During the experiment, he should demonstrate clearly what is meant by *supporting combustion* and *burning*. He should have the pupils compare the properties of CO and oxygen with respect to burning and supporting combustion. If there are some pupils in the class who still confuse the meaning of the two terms "burning" and "supporting combustion," he could perform a simple experiment on the preparation and properties of oxygen. For this particular class, the matter of weight was a greater disturbing factor than the confusion of the two terms just discussed. The demonstration experiment should make this distinction. However, the teacher should remind his pupils that in the test, the atomic weights and the weight of one liter of gas were given so that the pupil could easily calculate whether the gas is heavier or lighter than air, if he had forgotten the results of the experiments. At this point the method of finding the weight of a liter of gas from given data can be taught. The teacher can also point out that if the pupil remembered whether one of the gases, such as oxygen, is heavier or lighter than air, he could easily compare the molecular weights of the gases without going to the trouble to compute the weight of one liter. The teacher should also see that the pupils know that the atomic weight and

the molecular weight of argon are the same, since there is but one atom to the molecule instead of two.

So far in this chapter only those remedial measures which pertain to the class as a unit have been described. Let us now see what remedial measures are to be followed in the case of individual pupils. In Part I, the process and the time employed for remedial work will be short, due to the greater degree of simplicity of Part I. Individual pupils who have been especially weak in the properties of these gases should be given some simple laboratory experiments to perform. It might be said that among those pupils whose scores appear in Part I there is none in need of individual treatment. Simple experiments on the properties of oxygen, hydrogen, and carbon-monoxide would be well suited to the needs of pupils needing this remedial treatment. These gases will display readily the properties of burning, of supporting combustion, and of relative weights. Those pupils of this group who need assistance in the finding of the weight of a liter of gas will be placed in the remedial group which is receiving instruction in problem work.

In order to carry on this individual work efficiently, the teacher should have available mimeographed or carbon copies of exercises covering each topic. During the period in which the teacher meets all the pupils needing individual attention, he will give out to all the pupils who are weak in valence the exercises on valence. To those who are weak in nomenclature and who are not working valence exercises, he will give the nomenclature exercises. He will continue this procedure until all the pupils present are provided with exercises. After the pupils have started their work, the instructor will move around among the members of the group and give help where help is necessary. When a pupil has demonstrated his ability to work the exercises correctly, the teacher will then give him the next list of exercises which he is to work. By the end of the first remedial period the number of pupils needing assistance will be materially reduced, leaving probably only the chronic cases to be taken care of. These pupils may require assistance over a period of two weeks or more.

Since practically the whole class has encountered difficulty in problems and ions, these topics have been more carefully taken care of in the general class procedures. Therefore, the only pupils who will receive individual treatment in these two topics are those pupils who continue to have difficulty with the homework assignment on problems and ions. Throughout the process of individual treatment, the instructor will insist upon the pupil's mastery of one phase of his difficulty before he allows him to begin on the next step.

3. *For Checking the Results of Remedial Measures*

From a month to six weeks after remedial measures have been administered, a check should be made on the pupils' improvement by giving the other form of the diagnostic test in the mechanics of high school chemistry. The results should be analyzed in the same manner as were the results of Form A. Since Forms A and B are comparable, compute the improvement by subtracting the per cents correct in the Form A groups from the per cents correct in the Form B groups. The improvement or lack of improvement in the questions on valence, nomenclature, etc., can be readily determined. Not only can these general per cents be compared, but those individual scores which were low the first time can be compared with the individual scores in the second testing. It should not be necessary to institute general remedial treatment for the class this time. If general class treatment is required, it may be required for only one of the topics.

Just what per cents of correct responses to the various groups of questions is to be expected or to be aimed at, the writer does not know. He does feel, however, that a teacher may become over zealous in this field of chemistry and place a greater emphasis upon the mechanics of chemistry than is either wise or necessary. There are other phases of chemistry which are just as important and even more so than mechanics, and each teacher must choose for himself how he is to distribute his time and emphasis in the various phases of the subject.

By a procedure of testing and the application of remedial measures very similar to those described in this chapter, the

writer was able to note the improvement of his pupils during the school year 1926-1927. The greatest improvement occurred in problem work, but there was significant improvement in the writing of equations, valence, naming of formulas and equations.[46] During the second testing, fewer errors were made in valence and in the writing of equations of the completion and "entire" types. This showed that the pupil not only possessed a better understanding of the principle of valence, but he knew the valences of a greater number of elements and radicals. Just how pupils are to be taught to remember the valences of elements and radicals is a problem. If in his zeal to teach the pupils valence, the teacher has the pupils learn the valences of long lists of elements and radicals, the pupil soon learns to dislike the subject. A discussion of this topic properly belongs under the topic "improvement of teaching method" and will be taken up there in detail.

After the teacher has made a study of the improvement results, he can begin to see where remedial measures have proved effective and where they have not. He must then study the situation and see wherein he can improve his remedial procedures and where he will need to make changes in his teaching methods. The ordinary teacher will no doubt be glad to make changes in his methods of teaching, while the teacher with a scientific bent will try out controlled experiments upon his class groups in order to determine the most efficient teaching devices.

4. *For the Improvement of the Teaching Method*

In this section, only those phases of teaching method which are directly related to the topics presented in these diagnostic tests will be discussed. The order in which these phases will be developed will be that which is usually followed by most chemistry teachers during the school year. Since the metric system is employed throughout the course, this system and how to use it are usually taught quite early in the course. Since this system is used in the problems, and since one of the common types of error in the mechanics of problem solving is that of placing

[46] Malin, J. E.: "A Diagnostic Study of Students' Difficulties in Chemistry and the Effects of Application of Remedial Measures." Master's Thesis, 1927.

the decimal point, it is appropriate to make our start at this point.

Not only has an examination of the errors made in problems in Forms A and B and in the preliminary tests shown the presence of these errors but the testing of the writer's chemistry and physics classes in the metric system early in the school year has shown this type of error to be quite prevalent. To give such pupils a short course in decimals and label it a review of decimals would no doubt insult the dignity of juniors and seniors. However, such a course in decimals can be given in the metric system to those who need it and they will not think of it as a review course in decimals. The instructor can easily determine which pupils need this individual attention after he has given a short test in the metric system in problem solving. An analysis of the papers will reveal the fact that many of the pupils made mistakes not because they did not know the metric tables and how to use them but because they did not know where to place the decimal point. These pupils can be taught the principle of placing the decimal point and have practice in so doing by working metric problems.

It is also well at the beginning of the year to insist upon accurate work in all the mechanical phases pf problems. The need for accuracy can be impressed upon the pupils by deducting heavily from grades for papers where mechanical errors have been made. Thus, counting 50 per cent for principle and 50 per cent for errors in multiplication, division, etc., on every occasion will certainly constantly remind the pupil to be careful in his work. This incentive alone may not be sufficient to produce the desired results. The teacher must have at hand good illustrations which show how inaccuracy has caused loss of money in everyday life, how it has caused failure in certain large projects, and, on the other hand, how such projects as cutting tunnels through mountains by burrowing from both sides at the same time have been successful because of accurate computations. When the pupil once sees the uses of accuracy, he will be more willing to try to be accurate himself.

Evidence that these measures just described have produced results is shown in the data on problems in two of the writer's chemistry classes. His 1927 class and his 1925 class were com-

pared since both of these classes had taken Powers' Chemistry Test, Form B. The 1925 class had not been taught decimals by means of the metric system, nor had the importance of accuracy been emphasized in that class while in the 1927 class, the devices described above were used. A portion of the data will show the effect of these new measures.[47] Three things are significant in these data. In the first place, the per cent of problems wrong in 1927 is 21.7 less than in 1925. In the second place, the per cent of omissions in 1927 is 25.3 per cent less than it is in 1925. This would signify that more pupils tried the questions and, therefore, there should be greater opportunity to make both mechanical errors and errors in principle. The data show that the errors in principle are greater than in 1925 but the mechanical errors have been reduced from 8 per cent to 4.4 per cent.

1927 Per Cent of Problems Wrong—61.9		1925 Per Cent of Problems Wrong—82.6	
Per Cents of Errors		Per Cents of Errors	
Omissions	29.7	Omissions	55.0
Principle	56.0	Principle	37.0
Guessing	10.0		
Mechanics	4.4	Mechanics	8.0

Early in the course, the pupil performs experiments upon the gases, oxygen and hydrogen, and becomes acquainted with the terms "burns" and "supports combustion." Quite frequently the pupil thinks of burning as being identical with supporting combustion. The first time this idea appears the teacher should disabuse the pupil of it at once. This he can do in a number of ways. One way is to turn on the gas, light it and ask the pupil what is burning. Then hold a lighted match or burning taper in the air, blow out the flame and then ask if the oxygen in the room has been set on fire.

This confusion of terms was first brought to the writer's attention in general science a few years ago when a multiple choice test was given in which appeared the question: "Oxygen burns, supports combustion, has no weight, has color." Only 25 per cent of the class underscored "supports combustion". Of those who had underscored the wrong answer, 90 per cent of

47 Malin, J. E.: "A Diagnostic Study of Students' Difficulties in Chemistry and the Effects of Remedial Measures." Master's Thesis, 1927, p. 68.

them underscored "oxygen burns". During the next year, care was taken to present the topic of supporting combustion and burning in such a manner that the pupils could understand the difference in meaning in the two terms. In the test which followed, 96 per cent of the class answered the multiple choice question correctly and of those who answered it incorrectly not one underscored "oxygen burns". Similar results have occurred in the chemistry class from year to year. During the following year, a multiple choice test was given in the general science class in which one or more answers to the question were correct. In this test, 92 per cent of the pupils underscored "oxygen supports combustion" but 60 per cent of the class also underscored "oxygen burns". When the same question was tried on the chemistry class, 100 per cent of the pupils underscored the correct answer but 9 per cent also underscored "oxygen burns". As the result of these experiences the writer has deemed it important that the pupils receive and keep the correct impression as to the exact meaning of these terms from the very beginning of the chemistry course.

After the pupils have had an opportunity of becoming acquainted with several elements and compounds, the idea of formula writing is gradually introduced by having the formulas written under the names of the elements and compounds. When the pupils have received sufficient experience in seeing and writing the formulas of familiar compounds, they are taught the principle of valence as it applies to formula writing. At this point, the symbols of the elements and the valences of the elements and radicals are given. The pupils should be given sufficient practice in writing formulas under these conditions to enable them to understand the principle and apply it in the writing of the formulas. The exceptions to the principle and the reasons for these exceptions should not be taught until the pupils have formed the habit of writing the formulas of non-exceptions correctly. During the early stages of learning the principle of valence, two habits should become ingrained in the pupil's nervous system. He should in every case compute the total valences for the elements and radicals within the compound in order to make sure that the total plus valence equals the total minus valence. He should also be thoroughly im-

pressed with the idea that the smallest subscripts rather than their multiples must be used in writing the formulas.

To make sure that the pupil is thoroughly grounded in the principle, a few home work excercises in formula writing should be assigned from day to day. The question now arises, shall the pupil be required to memorize the valences of a list of elements and radicals or shall he be required to get them gradually? The writer has found from experience that to burden the pupils with memory lists causes a dislike for the subject on the part of the pupils. As the result of these experiences, the writer requires the pupils to know the valences only of the three or four very common radicals and the valences of five or six elements at the start. The pupils are then asked to observe the valence of elements and radicals as they write formulas in the laboratory and class. Since the same elements and radicals recur again and again, the pupils gradually learn their valences if they have formed the habit of noting valences each time the formulas are written. In this way, memorizing is not burdensome, and, moreover, the pupil soon realizes that he does not need to spend extra time looking up valences in valence tables. In other words, he learns to depend upon himself rather than upon the tables. The teacher can facilitate the formation of this habit by writing on the blackboard the name and formula of each new compound as it is studied. By having the pupils state the valences of the elements and radicals within the compound and by having them suggest the subscripts, both the valences and the principle of writing the formula will be impressed and retained on the minds of the pupils. The teaching of valence must be introduced gradually and must be taught constantly in very small portions at a time.

The principle of gradual introduction and constant usage not only applies in the teaching of valence but in the teaching of nomenclature, formulas, equations, and problems as well. After the pupils have learned the names of quite a number of elements and compounds through experience, the principles of nomenclature and formula writing are introduced. The analysis of the types of error made in these two related phases of chemistry shows us clearly that the teaching emphasis must be placed upon the principle of nomenclature and the knowing of the

fundamental formula. The principle of writing the formula from the name is taught simultaneously with the nomenclature. During this teaching process, the principle of valence should receive little attention. After the principle has been explained and illustrated, the teacher should work out with the class the naming and writing of a series of formulas for which the fundamental formula has been given. Home work assignments in the same kind of exercises should be given. From this time on, these principles can be kept fresh in the pupils' minds by having the pupils name and write the formulas of new compounds as they are studied. By being asked for the name and formula of the fundamental formula each time it occurs, the pupil begins to appreciate the application of the principle. By teaching in this manner, the teacher impresses upon the pupil that it is not necessary to memorize the name and formula of every compound he studies when only the knowledge of the fundamental formula and principle are necessary.

Like its predecessors, the equation must be introduced gradually and be used continually. The first chemical reactions which the pupils see in the laboratory are expressed in word equations. In time, the word equations appear with the formulas written under the names. When the pupils have received sufficient experience with various reactions and their word-formula equations, the principle of writing equations is taught. Only those reactions which the pupil has observed in the laboratory or has seen in his test are used. The first step to be taught is the balancing of equations. The pupil is shown and given practice in balancing equations, all of whose formulas are already given in the equation. The next step is the writing of molecular equations and balancing them. This is taught before double decomposition equations because the equations representing molecular reactions have been much more frequent up to the present time than have double decomposition equations. In this practice work, the equations with the atomic formulas for the elements and the formulas of any compound should be given. The pupils are then required to write molecular formulas for the atomic formulas, and then balance the equation.

Double decomposition equations are then taught from these reactions with which the pupil is already familiar. In this case, the formulas on the left hand side of the equation are given and the pupil is shown how the elements and radicals exchange places in forming the new compounds. The teacher should point out that the valences of the elements and radicals in the given formulas can be easily determined by applying the principle of valence. A few illustrations at this point will make clear just how the valences are determined. Having computed the valences, there should be no difficulty in writing the formulas of the products. Then, the operation is completed by balancing the equation. The pupils are then given practice and home assignments in the writing of double decomposition equations.

The next step is the teaching of completion equations which may or may not be double decomposition type. Reactions with which the pupils are already acquainted will be used. The fact which must be impressed upon the pupils' minds is that they must write their formulas on the right hand side of the equation before attempting to balance the equation. Errors in equation writing show that the pupils have changed formulas in order to make the equation balance. The pupils must therefore be made to realize that once they have written down the correct formulas, no changes whatever are to be made in the formulas in balancing the equation.

The last and most difficult form of equation to be taught is the entire equation in which the formulas for the reagents are not given. Much emphasis should not be placed on this particular type of equation at this time since the pupil has not had wide enough experience with chemical reactions. Then, too, his opportunities for writing this kind of equation will increase as he proceeds in the course. In his written work and in his tests, he will have opportunities to write the reaction for the preparation of certain acids, for the production of quick lime from limestone, etc. Besides, the pupil already has had practice in all the steps required in equation writing. However, a little practice in writing these entire equations will acquaint the pupil with this type.

Quite frequently the high school chemistry texts make the mistake of introducing the subject of laws too early in their

books. The pupil has not acquired as yet sufficient chemical knowledge to appreciate the meaning and applications of the laws. Thus the laws of conservation of matter, definite proportions, and multiple proportions appear in the very early chapters of the texts. Perhaps the authors think that chemistry pupils have already been acquainted with these laws in physics. But they cannot help knowing that pupils frequently take chemistry who have not studied physics, and that in some schools physics follows chemistry instead of preceding it. It is a little hard to see how the pupil can understand and appreciate the law of conservation of matter until he has performed a few quantitative experiments which show that the sum of the weights of the reagents is equal to the sum of the weights of the products. Furthermore, a knowledge of atomic and molecular weights is necessary before the teacher can demonstrate in an equation for a reaction that the sum of the molecular weights on the one side of the equation is equal to the sum of the molecular weights on the other side. As has been already stated in another way, the laws of conservation of matter, definite proportions, and multiple proportions are treated in the texts long before the pupil has had any quantitative laboratory experiments and long before he has learned how to write equations and determine the molecular weights of the elements and compounds within the equations. The authors' treatments of these laws are deductive in nature rather than inductive although the too brief approach to these laws is intended to be inductive.

The writer of this paper proposes that these laws should not be taught until the pupils have had much more laboratory experience including quantitative experiments and are capable of writing equations and of computing molecular weights within the equation. Then the teacher should introduce the various laws by having the pupils assemble and classify laboratory findings which have a bearing on the law to be studied. Any experimental data collected from the texts and references should also be collected and classified in the same manner. From these assembled data, the pupils should be encouraged to draw their own conclusions. Their conclusions should then be compared with the statements of the law as set forth in different texts. Having arrived at the statement of the law inductively

the pupil should experience no difficulty in illustrating the law. Furthermore, he should be given opportunities to apply the law. If it does not aid the pupil in this respect, it will certainly help him to understand the applications of the law when they are brought to his attention.

Several of the laws have direct applications in several types of problem which the pupil has to solve. The psychological moment for teaching these problems is the time immediately following the teaching of the law. Frequently these problems are taught without impressing upon the pupil the direct relationship between the law and the problem. The study of the combination of errors tends to verify the statement just made, for only a very small per cent of the pupils answered the question on the law and its application or problem correctly, while many more answered the law question correctly, but failed to use their knowledge in the problem or other application. These data signify that it behooves the teacher every time problems directly related to certain laws are assigned to connect these applications directly with the laws concerned. By so doing he will make sure that the pupil thoroughly understands the law and is able to apply it to the solving of problems.

Another topic which should be taught in conjunction with laws is theory. After the pupils have observed the related facts and drawn their conclusions they will, if they are at all curious, ask why these facts are true. It is at this point that the theories answer the whys and the wherefores. With the background which the pupil has secured in the proposed pathway to the knowledge of laws, he will be the more able to understand the theories and appreciate their value. It is certainly the duty of the teacher to show or, better still, have the pupils sense the value and use of theories to the scientist. Illustrations such as the theories employed by detectives or police in guiding them to a solution of a crime help the pupils to see the use of theories outside of the field of science. If teachers, then, are to make a more successful job of teaching laws to chemistry pupils they must revise their present method of teaching these laws. Experimentation will show whetеher the methods suggested here are efficient or not and will no doubt offer better procedures than those which have been proposed.

Two phases of the teaching of chemistry problems, the reduction of errors of a mechanical nature and the relationship of laws to problems, have already been discussed in this chapter and will not be repeated here. In the discussion of laws, however, no mention was made of the use of formulas. At the time when the laws are presented, the pupils should be taught to derive formulas from the statement of the law. Furthermore, the pupil should learn to formulate statements for the law from the formula. In other words, knowing the formula is an aid in recalling the law. Just as pupils have difficulties in the mechanics of problems such as decimals, division, etc., so they also have difficulty in solving formulas which are nothing more than simple algebraic equations. In spite of the fact that these pupils have studied algebra and have solved more difficult equations than those presented in the chemistry class, these simple formula equations give them plenty of difficulty. Just as in the case of reteaching decimals, time must be taken out by some of the pupils for learning the necessary transformation in the solution of formulas. Since the letters used in the formulas are not the same as the X's, Y's and Z's to which he has been accustomed in algebra, notation may be the cause of the difficulty. If the teacher in teaching those pupils who need help on this point shows the similarity between these formulas and similar equations in algebra the pupil will soon overcome his difficulty. The pupil should be taught to rely on the use of formulas since it simplifies the operation considerably.

A type of error which occurred quite frequently under principle was found in proportion. Quite frequently the direct proportion in an equation problem was made inverse or weights from other compounds in the equation than the ones to be used were frequently placed in the proportion. Since the subject of proportion is not emphasized in mathematics as it once was; since it always was and is a difficult subject for the pupil to master; and since proportion occupies an important place in chemistry problems, it is essential that the chemistry teacher provide a foundation in proportion. At the very start in these equation problems, the teacher must show the class how to set down the laboratory and atomic or molecular weights in a direct proportion, insisting that the laboratory weight if expressed in

a ratio must follow the same order as the atomic or molecular weights in the other ratio. Atomic or molecular weights may be compared with laboratory weights, but the order of arrangement must be the same in both cases. The pupil must be led to understand that volumes cannot be compared with weights. In such problems, volumes are to be changed to weights or weights are to be changed to volumes before the proportion can be formed, or gram molecular weights are to be compared with gram molecular volumes in the proportion.

Another common type of error in principle in equation problems occurred in the molecular weights. The pupil forgot to multiply the number of atoms by the atomic weight of the element or, if there was more than one molecular weight, he forgot to multiply the molecular weight by the number of molecules. The pupil should be taught the correct method of computing molecular weights and be given practice in doing so. The teacher can call to the pupils' attention the fact that pupils forget to multiply the atomic weights by the number of atoms or they forget to multiply the molecular weights by the number of molecules.

Boyle's law is about the only place where the pupil has to write an inverse proportion. The pupil should be shown the meaning of inverse proportions through various illustrations. He, then, should be required to produce similar situations. If he has difficulty in solving questions of this kind, he should solve his questions by the formula.

In the case of Charles's law, the emphasis must be placed upon the conversion of the centigrade readings to absolute readings. The formula can then be used to solve the problem. When applications of both Charles's and Boyle's laws occur in the problems, teaching the pupils to use the formula is by far the easier method of teaching this type of problem. Care must be taken in showing the pupil how to set down the statements in the problem so that their numbers can be substituted most easily in the formula. For pupils who make mistakes easily, this setting down of the statements of the problem in such a manner as to facilitate their substitution in the formula certainly eliminates quite a number of careless mistakes.

In those problems requiring the pupils to find the weight of a liter of gas, the most common error was failure to complete all the operations. Thus if the pupils solved the problem by the method which requires two operations, they only performed one and, if they solved the problem by the 22.4 liters method, where only one operation was needed, they called 22.4 liters the answer. At other times they multiplied when they should have divided. When this type of problem is taught, it should be definitely pointed out to the pupil just how many operations there are and the reason for each. If the pupil really knows the reasons for the operations, he will use all the operations necessary and he will not multiply when he should divide.

Another type of problem, which is just the reverse of this type, should be taught at the same time. This is the type in which the weight of the liter of gas is given and the pupil has to compute the molecular weight. By computing the weight of one liter and then from his answer calculating the molecular weight, the pupil will see that the second question can be solved by working the first backwards. However, to insure full understanding, the pupil must see the reasons that he multiplies and divides, so that he will not confuse the two procedures, as did those who made errors in principle in the tests.

In the problem of volumes on Gay Lussac's law, pupils made the error of comparing volumes with molecular weights. This is an error which they should have been warned against in their work with equation problems. Had they had a complete understanding of Gay Lussac's law, they would have known that they could have compared the numbers of molecules with volumes. The pupils failed on this problem because the relationship of this type of problem to Gay Lussac's law had never been made clear to them. Had the teachers impressed upon the pupils that this problem is an application of Gay Lussac's law, and had these pupils been required to look up Gay Lussac's law at the time, the number of pupils failing on this problem would have been materially reduced.

In the problems on finding the simple formula whose percentage composition is given, an utter lack of understanding of the principle is the cause for the high per cents of errors. Not only must the pupils be taught the principle, but they must be

shown the reason for dividing the per cents by the atomic weights. Otherwise they will divide atomic weights by per cents or per cents by per cents, etc. It is true that it is a little difficult to show the pupils why per cents are divided by atomic weights. Yet it can be done and should be done; otherwise the pupil will try to memorize the process without knowing the reason for his computation, and at a later time, when he is called upon to use the process his memory will fail to function accurately. The remaining step is easy to teach and easily comprehended by the pupils.

5. Conclusions

1. The data and discussion in this chapter have shown that these chemistry tests can and should be used to diagnose the pupils' difficulties in the mechanics of high school chemistry.

2. As a result of the diagnostic procedure, certain remedial measures have been proposed which have resulted in improvements in the case of the writer's chemistry classes.

3. These diagnostic tests can be used to measure improvement due to the application of remedial measures.

4. As a result of this diagnostic study, improved methods of teaching the topics included in the mechanics of high school chemistry have been proposed.

CHAPTER VI

CONCLUSIONS

1. *Validity*

These diagnostic tests in the mechanics of High School chemistry and its related fundamentals are valid for the following reasons:

1. The material contained in the tests, Forms A and B, represent the greatest proportion of subject matter on the mechanics and its related fundamentals found in the most widely used high school chemistry textbooks and manuals.

2. An analysis of the College Entrance Board Examinations from 1917 to 1927 shows that 44.02 per cent of their questions covers the kinds of material contained in the diagnostic tests.

3. The material contained in the diagnostic tests is taught in the public secondary schools of the United States, since the answers to 96 questionnaires received from 96 cities, representing every state in the Union with the exception of Nevada, show that these city systems teach said fundamentals in chemistry. Furthermore, the writer's personal interviews with chemistry teachers of 19 schools in and around Philadelphia verifies this conclusion.

4. The material contained in these tests appears in the "Revised Report of a Standard Minimum High School Course in Chemistry," proposed by the Committee of Chemical Education of the American Chemical Society, one of whose objectives was to list only those topics which are common to all localities.

5. The materials selected for the tests are in agreement with those topics which were considered fundamental in the questionnaire investigation undertaken by the Chemistry Section of the Central Association of Science and Mathematics Teachers in 1920.

6 The selection and arrangement of items into steps for the testing of separate abilities and complex abilities varying in degree of complexity, are based upon previous studies made by

the writer of the types of error committed by pupils in the mechanics of high school chemistry.

7. The analysis of the types of error made in the present tests shows that these tests diagnose the difficulties they were designed to diagnose.

8. The results of the tests are valid since the conditions for the administration, scoring, and analysis of the tests have been uniform.

9. The results should also be valid for the reason that a sufficiently large number of schools and pupils were represented in the whole investigation. A total of 19 schools has been involved in the actual testing. In all, 624 pupils took Form A; 584, Form B; 160, Form X; 262 Form Y; and 330 the preliminary test, making a total of 1960 pupils.

10. The curves for the percentile distribution of the scores of Form A for the two different groups of pupils is very similar. The same is true in regard to the curves for Form B.

11. The degree of similarity between the percentile graphs of Form A for the two testing periods is very high when compared with the percentile graphs of Form B for the corresponding testing periods.

2. *Diagnostic Results*

The following conclusions are drawn in regard to the analysis of the data:

1. A study of the distribution of scores shows that Form A is slightly more difficult than Form B, and that this greater degree of difficulty is in Part I of Form A. This study also shows that Part II is by far a more difficult portion of the test than Part I.

2. An analysis of the data by the per cents of correct responses to each item shows that the ten items on argon in Form A are more difficult than the ten similar items in Part I of Form B on helium. The least difficult items are those on oxygen and hydrogen.

3. The most difficult items in Part I of each test are those which treat of weight and the supporting of combustion.

4. When the questions of Part II in each test are classi-

fied into seven groups and then arranged in order from the highest to the lowest from the standpoint of average per cents of correct responses, the following orders result: Form A; 1. Valence, 2. Nomenclature, 3. Laws, 4. Equations, 5. Formulas, 6. Problems, 7. Ions; Form B; 1. Valence, 2. Equations, 3. Laws, 4. Nomenclature, 5. Formulas, 6. Problems, 7. Ions.

5. An analysis of the types of error reveals the following facts:

A. The types of error occurring in Form A are practically the same as those occurring in form B.

B. Those types of error which occur most frequently in Form A occur most frequently in Form B.

C. The type of error labelled "omissions" is present in every question and has the highest frequency of all types of error.

D. In valence, practically all the errors can be classified under principle. The most prevalent sub-type of error in this group is the misplacing of subscripts.

E. The principal causes for errors in nomenclature are lack of knowledge of the principle, lack of knowledge of the fundamental formula, and both of these causes.

F. The causes for errors in formulas can be attributed to a lack of understanding of the principle, lack of knowledge of the valences, lack of knowledge of the symbols of the elements, and various combinations of the causes just stated.

G. In equations, the chief types of error are omissions, not finished, balance, valence, formula, product, extra-product, and molecular formula. Where the pupils were required to write formulas, lack of knowledge of the valences, or a lack of knowledge of the valence principle constitutes the principal difficulty throughout.

H. In the writing of ions and ionic equations, lack of knowledge of the principles involved constitutes the main difficulty.

I. In problems, the chief errors occur in principle and mechanics, the errors in principle being by far the more frequent.

J. In laws, aside from omissions, the greatest difficulty lies in the underscoring of those responses which most nearly resemble the correct responses.

6. A study of combinations of errors in Part I on the three questions as to weight of a gas gives the combination *heavier than air and lighter than air* the greatest frequency.

The most frequent combination of errors on the three questions concerning supporting of combustion occurs in "burns in air" and "a lighted stick thrust into it goes out."

7. A study of the combination of errors in Part II on pairs of questions related to laws, definitions, and their applications shows that very few pupils could answer both questions correctly. The number of correct responses to laws and definitions far outnumbered the correct responses to their applications.

8. An analysis of the types of error in Part I of each test shows but two types—omissions and wrong answers. In some cases, all ten items on a given gas were omitted. Since there are quite a large number of omissions, it is evident that pupils followed the directions, and that guessing in Part I was kept at a minimum.

3. *Results of Revision in Forms A and B*

The conclusions regarding the proposed minor revisions for Forms A and B, as tried out in Forms X and Y, are stated as follows:

1. The proposed revisions for the questions in valence and ionization in Forms A and B will have little or no effect upon the distribution of scores of these tests in future trials, and they will tend to increase the diagnostic value of the tests for the following reasons:

A. The per cents of correct responses to the valence questions in Form X approximately equal the per cents to the responses of the same questions in Forms A and B.

B. The per cents of correct responses to the ion questions in Form X, although they show wide discrepancy in the case of one question, when compared with the per cents of the

same questions in Forms A and B, are not sufficiently divergent to cause any appreciable change in the distribution of scores. Of those pupils taking Forms A and B who misunderstood the directions for the ion questions, from one-fourth to one-half of them showed a partial knowledge of the ion principle in writing the ionic equation, and out of this same group of pupils making this type of error only two pupils wrote the ionic equation correctly.

C. The diagnostic value and the accuracy in scoring the questions on valence have been increased because it is now possible to see at a glance whether the questions are omitted or thought to be correct as stated in the question.

2. The substitution of the theory of valence item for the law of multiple proportions will increase the validity of the test, since the relationship between the theory of valence and the principle of valence is of a much higher order than that between the law of multiple proportions and the computation of a formula. The types of error made on this item in Form Y show that this valence theory question is valid for diagnosis.

3. The inclusion of the percentage composition type of problem in the final forms of the test is justifiable for the following reasons:

A. Textbook analysis ranks it fourth in importance among the various types of problem.

B. This same principle is present in certain equation problems and in per cent problems.

C. This type of problem contains the molecular weight principle, which is common to other types of problem.

D. An analysis of the results of this problem in Form Y shows that the item is diagnostic since the types of error fall under the headings of "principle" and "mechanics."

4. *Use of the Tests*

1. Forms A and B are to be used in diagnosing pupils' difficulties in the mechanics of high school chemistry and its related fundamentals.

2. Remedial measures can be applied as the result of the diagnosis.

3. These tests can be used to measure improvement after the application of remedial measures.

4. The use of these tests should prove helpful in the improvement of the methods of teaching this limited field of the fundamentals of high school chemistry.

APPENDIX

TABLE LXVII

TOTAL NUMBER AND PER CENT OF PAGES DEVOTED TO THE SUB-TOPICS IN GASES IN THE FIVE SELECTED TEXTBOOKS

Sub-Topic	Number of Pages	Per Cent of Total Space
Occurrence	12.8	.59
Preparation	68.9	3.17
Properties	61.5	2.83
Uses	54.9	2.54
Miscellany	46.5	2.15
Total	244.6	11.28

TABLE LXVIII

TOTAL NUMBER AND PER CENT OF PAGES DEVOTED TO LAWS AND THEORIES IN THE FIVE SELECTED TEXTBOOKS

TOPIC	TEXTBOOKS					Total No. of Pages	Average No. of Pages	Per Cent o Total Space
	A	B	C	D	E			
Principle of Valence	4.8	1.2	3.2	6.3	3.2	18.7	3.74	.86
Theory of Valence	1.8	.0	.0	.0	.0	1.8	.36	.08
Electron Theory	.0	.0	.0	.0	7.5	7.5	1.50	.35
Theory of Ionization	11.0	9.6	7.1	11.5	4.4	43.6	8.72	2.01
Law of Dulong and Petit	.0	.0	.0	.3	.0	.3	.06	.01
Law of Conservation of Matter	.6	.5	.3	.4	.3	2.1	.42	.10
Law of Conservation of Energy	.4	.0	.3	.2	1.0	1.9	.36	.09
Law of Definite Proportions	.4	.2	.4	.5	.6	2.1	.40	.10
Law of Multiple Proportions	.7	.1	.8	.6	.8	3.0	.60	.14
Gay Lussac's Law of Volumes	.6	.3	.7	1.1	.7	3.4	6.80	.16
Henry's Law	.3	.1	.4	.0	.0	.8	.16	.04
Avagadro's Hypothesis	2.6	2.3	.8	.6	1.2	7.5	1.50	.35
Law of Charles	2.4	2.5	1.8	1.0	1.0	8.7	1.74	.40
Law of Boyle	3.4	2.5	1.0	1.0	1.0	8.9	1.78	.41
Law of Mass Action	2.4	5.2	1.7	.3	3.0	12.6	2.52	.58
Laws of Bertholet	1.3	2.2	1.5	.0	4.0	9.0	.18	.41
Periodic Law	5.6	8.0	6.6	6.0	1.5	27.7	5.54	1.28
Law of Octaves	.2	.3	.0	.0	.0	.5	.10	.02
Atomic Numbers	2.3	.0	.0	.0	.0	2.3	.46	.11
Atomic Theory	2.5	3.7	3.0	2.8	.4	12.4	2.48	.57
Kinetic Molecular Theory	1.0	.0	.3	.0	2.0	3.3	.66	.15
Phlogiston Theory	.0	.0	.4	.3	.4	1.1	.22	.05
Combining Weights	1.8	2.7	1.7	2.1	.1	8.4	1.68	.39
Principle of Nomenclature	1.8	3.2	1.2	.6	1.0	7.8	1.56	.36
Total	47.9	44.6	33.2	35.6	34.1	195.4	43.54	9.02

TABLE LXIX

TOTAL NUMBER AND PER CENT OF PAGES DEVOTED TO DIFFERENT TYPES OF EQUATION IN THE FIVE SELECTED TEXTBOOKS

TYPE	TEXTBOOKS					Total No. of Pages	Average No. of Pages	Per Cent of Total Space
	A	B	C	D	E			
Word	1.0	.4	.8	.5	1.3	4.0	.80	.18
Decomposition	1.1	1.2	1.4	1.0	1.0	5.7	1.14	.26
Synthesis	1.7	2.3	1.5	1.4	2.7	9.6	1.92	.44
Single displacement	1.0	1.4	1.1	1.8	.3	5.6	1.12	.26
Metathesis	3.5	2.3	2.7	1.6	4.5	14.6	2.92	.67
Metathesis and decomposition	.2	.5	.1	.1	.4	1.3	.26	.06
Oxidation & reduction	2.6	3.7	2.9	2.9	3.0	15.1	3.02	.70
Ionic	1.2	1.1	.4	.5	1.9	5.1	1.02	.23
Total	12.3	12.9	10.9	9.8	15.1	61.0	12.20	2.80

TABLE LXX

TOTAL NUMBER AND PER CENT OF PAGES DEVOTED TO PROBLEMS IN THE FIVE SELECTED TEXTBOOKS

TYPE	TEXTBOOKS					Total No. of Pages	Average No. of Pages	Per Cent of Total Space
	A	B	C	D	E			
Metric	.5	.0	.0	1.2	.1	1.8	.36	.08
Equation	6.7	10.2	4.8	8.0	7.0	36.7	7.34	1.69
Combining volumes	.3	.4	.0	.2	.2	1.1	.22	.05
Equivalent weight	.2	.0	.1	.4	.0	.7	.14	.03
Gram-molecular weights	.0	.0	.0	.0	.0	.0	.00	.00
M. W. from atomic weights	.0	.1	.1	.2	.2	.8	.12	.03
M. W. from depression of freezing point	.1	.0	.0	.0	.0	.1	.02	.004
M. W. from Sp. Gr. of the gas	.0	.1	.0	.0	.0	.1	.02	.004
M. W. from Wt. of Vol	.8	2.5	.0	.1	.0	3.4	.68	.16
Percentage composition	1.1	1.1	.7	2.4	.7	6.0	1.20	.28
Per cent	.6	.1	.9	1.3	.6	3.5	.70	.16
Compute formula	3.8	3.8	1.1	1.0	.0	9.7	1.94	.45
Compute number of atoms	.0	1.2	.0	.0	.0	1.2	.24	.06
Compute weight of 1 liter of gas	.8	.2	.1	.0	.7	1.8	.36	.08
Change volume to weight	.1	.2	.2	1.4	.0	1.9	.38	.09
Change weight to volume	.1	.4	.2	1.2	.1	2.0	.40	.09
Find Sp. Gr. of gases (to air & to hydrogen)	.3	.4	.0	.0	.1	.8	.16	.04
Density of solids and liquids	.0	.1	.0	.3	.4	.8	.16	.04
Laws of Boyle and Charles	4.8	4.2	1.7	3.1	2.4	16.2	3.24	.75
Density and pressure	.0	.0	.0	.0	.0	.0	.00	.00
Alkalimetry and acidimetry	.0	.0	.0	.4	.0	.4	.08	.02
Solubility of gases	.0	.0	.0	.0	.1	.1	.02	.004
Calories	.0	.0	.2	.0	.0	.2	.04	.01
Heat of combustion	.0	.0	.0	.0	.2	.2	.04	.01
Carat (gold)	.0	.0	.0	.0	.0	.0	.00	.00
Proportion	.0	.0	.0	.0	.1	.1	.02	.004
Ratio	.0	.0	.0	.0	.0	.0	.00	.00
Find valence	.0	.0	.0	.0	.0	.0	.00	.00
Henry's Law	.0	.0	.1	.0	.0	.1	.02	.004
Find atomic weight	.0	.0	.0	.6	.0	.6	.12	.03
Miscellany	.0	.0	.0	.0	.1	.1	.02	.004
Total	20.2	25.0	10.2	21.8	13.0	90.2	18.04	4.39

TABLE LXXI

TOTAL NUMBER AND PER CENT OF PAGES DEVOTED TO THE SUB-TYPES OF PROBLEM IN THE FIVE SELECTED TEXTBOOKS

SUB-TYPE	TEXTBOOKS					Total No. of Pages	Average No. of Pages	Per Cent of Total Space
	A	B	C	D	E			
Alkalimetry and Acidimetry								
Finding weight of solute	.0	.0	.0	.1	.0	.1	.02	.004
Finding normality	.0	.0	.0	.0	.0	.0	.00	.00
Finding concentration	.0	.0	.0	.0	.0	.0	.00	.00
Finding volume	.0	.0	.0	.3	.0	.3	.06	.01
Total	.0	.0	.0	.4	.0	.4	.08	.02
Computing atomic weight								
From weight of volume	.0	.0	.0	.1	.0	.1	.02	.004
From density and per cent composition	.0	.0	.0	.0	.0	.0	.00	.00
From per cent composition, M. W., and number of atoms	.0	.0	.0	.2	0	.2	.04	.01
From specific heat & atomic Wts.	.0	.0	.0	.2	.0	.2	.04	.01
From M.W. & per cent composition	.0	.0	.0	.1	.0	.1	.02	.004
From M.W. & atomic weight	.0	.0	.0	.0	.0	.0	.00	.00
From per cent composition and atomic weight	.0	.0	.0	.0	.0	.0	.00	.00
Total	.0	.0	.0	.6	.0	.6	.12	.03
Density of solids and liquids								
Finding density	.0	.0	.0	.1	.4	.5	.10	.02
Finding volume	.0	.0	.0	.1	.0	.1	.02	.004
Finding weight	.0	.1	.0	.1	.0	.2	.02	.01
Total	.0	.1	.0	.3	.4	.8	.14	.04
Miscellaneous problems involving:								
Finding weight of solvent	.0	.0	.0	.0	.0	.0	.00	.00
Weight of air over given area	.0	.0	.0	.0	.0	.0	.00	.00
Use of tables	.0	.0	.0	.0	.0	.0	.00	.00
Addition of weights	.0	.0	.0	.0	.0	.0	.00	.00
Reduction of Centigrade reading to Fahrenheit	.0	.0	.0	.0	.0	.0	.00	.00
Reduction of Centigrade reading to Absolute	.0	.0	.0	.0	.0	.0	.00	.00
Finding length, shape changed, volume constant	.0	.0	.0	.0	.1	.1	.02	.004
Finding cost of composite, ratios & price per ingredient given	.0	.0	.0	.0	.0	.0	.00	.00
Total	.0	.0	0	.0	.1	.1	.02	.004

TABLE LXXI—*continued*

TOTAL NUMBER AND PER CENT OF PAGES DEVOTED TO THE SUB-TYPES OF PROBLEM IN THE FIVE SELECTED TEXTBOOKS

SUB-TYPE	TEXTBOOKS					Total No. of Pages	Average No. of Pages	Per Cent of Total Space
	A	B	C	D	E			
Equation problems involving								
Weights	3.0	4.2	3.2	4.7	3.7	18.8	3.76	.87
Weights & per cent of purity	1.0	.3	.6	.9	.9	3.7	.74	.17
Volume and weight	1.5	3.9	.7	1.0	1.4	8.5	1.70	.39
Volumes	1.2	1.7	.3	.1	.8	4.1	.82	.19
Computing atomic weight	.0	.1	.0	1.1	.0	1.2	.24	.06
Volume, weight, & per cent of purity	.0	.0	.0	.2	.2	.4	.08	.02
Total	6.7	10.2	4.8	8.0	7.0	36.7	7.34	1.69
Percentage composition computed.								
From the formula	1.1	.7	.4	2.2	.6	5.0	1.00	.23
From weight of constituents	.0	.4	.3	.2	.1	1.0	.20	.05
Total	1.1	1.1	.7	2.4	.7	6.0	1.20	.28
Per cent problems involving								
Finding weight	.6	.1	.8	1.2	.6	3.3	.66	.15
Finding volumes	.0	.0	.1	.1	.0	.2	.04	.01
Finding per cent composition by volume	.0	.0	.0	.0	.0	.0	.00	.00
Per cent of element as per cent of oxide	.0	.0	.0	.0	.0	.0	.00	.00
Finding profit and loss	.0	.0	.0	.0	.0	.0	.00	.00
Total	.6	.1	.9	1.3	.6	3.5	.70	.16
Formula - Computing the simple								
Formula	3.1	2.4	1.1	.7	.0	7.3	1.46	.34
True formula	.7	1.4	.0	.3	.0	2.4	.48	.11
Total	3.8	3.8	1.1	1.0	.0	9.7	1.94	.45
Laws of Boyle and Charles								
Boyle	.7	1.0	.3	.5	.4	2.9	.58	.13
Charles	.7	.0	.3	.7	.5	3.0	.60	.14
Boyle and Charles	1.4	.5	.8	1.3	1.5	5.5	1.10	.25
Boyle & Charles with corrections	1.7	1.9	.3	.1	.0	4.0	.80	.18
Boyle & Charles, find weight	.3	.0	.0	.5	.0	.8	.16	.04
Total	4.8	4.2	1.7	3.1	2.4	16.2	3.24	.75

TABLE LXXII

THE RANKING OF THE GASES FROM THE ANALYSIS OF FIVE SELECTED TEXTBOOKS, FIVE SELECTED MANUALS, AND COLLEGE ENTRANCE BOARD EXAMINATIONS

TOPIC	No. of Books Containing the Topic		Per Cent of Total Space Devoted to the Topic in		Per Cent of Total No. of College Entrance Board Questions	Average Per Cent	Rank
	Texts	Manuals	Texts	Manuals			
Oxygen	5	5	2.39	.62	.56	1.19	1
Hydrogen	5	5	1.52	.89	.45	.95	2
Ammonia	5	5	.97	.45	1.06	.83	3
Chlorine	5	5	1.15	.49	.78	.81	4
Carbon dioxide	5	5	.76	.50	.50	.29	5
Nitrogen	5	5	1.00	.32	.34	.55	6
Carbon monoxide	5	3	.33	.25	.73	.44	7
Hydrogen sulphide	5	5	.44	.28	.56	.43	8
Sulphur dioxide	5	4	.53	.31	.17	.34	9
Hydrogen chloride	5	5	.43	.32	.11	.59	10
Nitric oxide	5	4	.13	.21	.39	.24	11
Nitrous oxide	5	2	.12	.09	.34	.18	12
Acetylene	5	2	.28	.04	.06	.13	13
Methane	5	3	.17	.08	.11	.12	14
Helium	5	0	.13	.00	.17	.10	15
Ozone	4	1	.18	.04	.00	.07	16.5
Fluorine	5	0	.21	.00	.00	.07	16.5
Hydrogen bromide	5	5	.06	.05	.00	.04	19
Hydrogen dioxide	5	4	.09	.03	.00	.04	19
Argon	4	0	.12	.00	.00	.04	19
Hydrogen iodide	2	3	.02	.03	.00	.02	22
Ethylene	4	0	.05	.00	.00	.02	22
Arsine	2	0	.05	.00	.00	.02	22
Nitrogen tetroxide	3	0	.04	.00	.00	.01	26.5
Cyanogen	3	0	.02	.00	.00	.01	26.5
Phosphine	2	0	.02	.00	.00	.01	26.5
Phosgene	2	0	.03	.00	.00	.01	26.5
Chloro-picrin	2	0	.03	.00	.00	.01	26.5
Neon	4	0	.02	.00	.00	.01	26.5

TABLE LXXIII

FREQUENCY OF OCCURRENCE OF THE PROPERTIES OF GASES IN THE FIVE SELECTED TEXTBOOKS

PROPERTIES	TEXTBOOKS					Total Frequency
	A	B	C	D	E	
PHYSCIAL						
Color	15	16	21	20	8	80
Odor	15	13	15	16	6	65
Taste	8	5	8	7	3	31
Weight	15	10	10	10	4	49
Solubility in water	16	12	12	12	6	58
Fumes in presence ot moisture	2	2	1	1	0	6
Liquefaction	8	7	8	7	0	30
Solidification	5	4	5	3	2	19
Occlusion	1	1	1	1	0	4
CHEMICAL						
Supports combustion	10	7	7	9	2	35
Combustibility	13	7	7	11	5	43
Oxidizing agent	2	1	2	1	2	8
Reducing agent	7	4	4	3	1	19
Inert	4	3	2	2	0	11
Bleaching	5	3	3	1	1	13
Poisonous	7	4	7	8	4	30
Supports Life	1	1	1	1	1	5

TABLE LXXIV

FREQUENCY OF OCCURRENCE AND RANK OF PROPERTIES OF GASES IN THE FIVE SELECTED TEXTBOOKS AND FIVE SELECTED MANUALS

ITEM	No. of Text-Books Containing the Item	No. of Manuals Containing the Item	Total Frequency in the Text-Books	Total Frequency in the Manuals	Total Frequency	Rank
PHYSICAL PROPERTIES						
Color	5	5	80	35	115	1
Odor	5	5	65	32	97	2
Taste	5	5	31	5	36	5
Weight	5	5	49	22	71	4
Solubility in water	5	5	58	33	91	3
Fumes in presence of moisture	4	4	6	4	10	8
Liquefaction	4	0	30	0	30	6
Solidification	5	0	19	0	19	7
Occlusion	4	0	4	0	4	9
CHEMICAL PROPERTIES						
Supports combustion	5	5	35	33	68	2
Combustibility	5	5	43	32	75	1
Oxidizing agent	5	1	8	2	10	7
Reducing agent	5	5	19	9	26	4
Inert	4	0	11	0	11	6
Bleaching	5	5	13	10	23	5
Poisonous	5	4	30	10	40	3
Supports life	5	2	5	2	7	8

TABLE LXXV

THE RANKING OF LAWS AND THEORIES FROM THE ANALYSIS OF COLLEGE ENTRANCE BOARD EXAMINATIONS AND FIVE SELECTED TEXTBOOKS

TOPIC	No. of Texts Containing the Topic	Per Cent of Total Space Devoted to the Topic in the Five Texts	Per Cent of Total No. of College Entrance Board Questions	* Weighted Average	Rank
Theory of Ionization	5	2.01	1.06	1.69	1
Periodic Law	5	1.28	.34	.97	2
Atomic Theory	5	.57	.34	.49	3
Avagadro's Hypothesis	5	.35	.50	.40	4
Law of Mass Action	5	.58	.00	.39	5.5
Law of Boyle	5	.41	.34	.39	5.5
Law of Charles	5	.40	.28	.36	7
Law of Multiple Proportions	5	.14	.67	.32	8
Laws of Bertholet	4	.41	.00	.27	9.5
Kinetic Molecular Theory	3	.15	.50	.27	9.5
Gay Lussac's Law of Volumes	5	.16	.45	.26	11.5
Combining Weights	5	.39	.00	.26	11.5
Electron Theory	1	.35	.00	.23	13
Law of Definite Proportions	5	.10	.34	.18	14
Law of Conservation of Matter	5	.10	.28	.16	15
Law of Conservation of Energy	4	.09	.17	.11	16
Atomic Numbers	1	.11	.00	.07	17
Theory of Valence	1	.08	00	.05	18
Henry's Law	3	.04	.00	.03	19
Theory of Phlogiston	3	.05	.00	.03	20
Law of Octaves	1	.02	.00	.01	21
Law of Dulong and Petit	2	.01	.00	.01	22

*Textbooks are given a weight of 2 and College Entrance Board Examinations a weight of 1.

TABLE LXXVI

THE RANKING OF EQUATIONS FROM THE ANALYSIS OF COLLEGE ENTRANCE BOARD EXAMINATIONS AND FIVE SELECTED TEXTBOOKS

TYPE	No. of Texts Containing the Type	Per Cent of Total Space Devoted to the Topic in the Five Texts	Per Cent of Total No. of College Entrance Board Questions	* Weighted Average	Rank
Metathesis	5	.67	4.47	1.94	1
Oxidation and Reduction	5	.70	4.21	1.87	2
Synthesis	5	.44	1.57	.82	3
Decompos tion	5	.26	.78	.43	4
Single Displacement	5	.26	.73	.42	5
Metathesis and Decomposition	5	.06	.73	.28	6
Ionic	5	.23	.34	.27	7
Word	5	.18	.00	.12	8

*Textbooks are given a weight of 2 and College Entrance Board Examinations, weight of 1.

TABLE LXXVII

THE RANKING OF PROBLEMS FROM THE ANALYSIS OF COLLEGE ENTRANCE BOARD EXAMINATIONS AND FIVE SELECTED TEXTBOOKS

TYPE	No. of Texts Containing the Type	Per Cent of Total Space Devoted to the Topic in the Five Texts	Per Cent of Total No. of College Entrance Board Questions	Weighted Average	Rank
Equations	5	1.69	3.30	2.23	1
Laws of Boyle and Charles	5	.75	.62	.71	2
Compute formula	4	.45	.62	.51	3
Percentage composition	5	.28	.62	.39	4
M. W. from weight of volume	3	.16	.28	.20	5
Per cent	5	.16	.00	.11	6
Alkalimetry and acidimetry	1	.02	.22	.09	7
Equivalent weight	3	.03	.17	.08	8
Compute weight of 1 liter of gas	4	.08	.06	.07	9
Compute number of atoms	1	.06	.06	.06	11
Change volume to weight	4	.09	.00	.06	11
Change weight to volume	5	.09	.00	.06	11
Metric	3	.08	.00	.05	13
M. W. from atomic weight	4	.03	.06	.04	14
Combining volumes	4	.05	.00	.03	16
Find Sp. Gr. of gases (to air and to hydrogen)	3	.04	.00	.03	16
Density of solids and liquids	3	.04	.00	.03	16
Find valence	0	.00	.06	.02	20
Find atomic weight	1	.03	.00	.02	20
Miscellany	1	.004	.06	.02	20
Calories	1	.01	.00	.01	22.5
Heat of combustion	1	.01	.00	.01	22.5
M. W. from depression of freezing point	1	.004	.00	.003	25
M. W. from Sp. Gr. of the gas	1	.004	.00	.003	25
Solubility of gases	1	.004	.00	.003	25
Proportion	1	.004	.00	.003	25
Henry's Law	1	.004	.00	.003	25
Gram-molecular weight	0	.00	.00	.00	29.5
Density and Pressure	0	.00	.00	.00	29.5
Carats (gold)	1	.00	.00	.00	29.5
Ratio	0	.00	.00	.00	29.5

TABLE LXXVIII

THE RANKING OF SUB-TYPES OF PROBLEMS FROM THE ANALYSIS OF THE COLLEGE ENTRANCE BOARD EXAMINATIONS AND FIVE SELECTED TEXTBOOKS

SUB-TYPE	No. of Texts Containing the Sub Type	Per Cent of Total Space Devoted to the Sub-Type in the Five Texts	Per Cent of Total No. of College Entrance Board Questions	Weighted Average	Rank
Equation problems involving					
Weights	5	.87	1.17	.97	1
Volume and weight	5	.39	1.23	.67	2
Volumes	5	.19	.90	.43	3
Weights and per cent purity	5	.17	.00	.11	4
Computing atomic weight	2	.06	.00	.04	5
Volume, weight, & per cent purity	2	.02	.00	.01	6
Total	5	1.69	3.30	2.23	
Percentage composition computed					
From the formula	5	.23	.56	.34	1
From the weights of constituents	4	.05	.06	.05	2
Total	5	.28	.62	.39	
Per cent problems involving					
Finding weights	5	.15	.00	.10	1
Finding volumes	2	.01	.00	.01	2
Finding per cent composition by volume	0	.00	.00	.00	4
Per cent of element in ore to be expressed as per cent of oxide	0	.00	.00	.00	4
Finding profit and loss	0	.00	.00	.00	4
Total	5	.16	.00	.11	
Formula					
Computing the simple formula	4	.34	.39	.36	1
Computing the true formula	3	.11	.22	.15	2
Total	4	.45	.61	.51	
Laws of Boyle and Charles					
Charles	5	.14	.45	.24	1
Boyle and Charles	5	.25	.11	.20	2
Boyle and Charles with corrections	4	.18	.00	.12	3
Boyle	5	.13	.06	.11	4
Boyle and Charles: find weight	2	.04	.00	.03	5
Total	5	.75	.62	.70	
Alkalimetry and acidimetry					
Finding concentration	0	.00	.22	.07	1
Finding volume	1	.01	.00	.01	2
Finding weight of solute	1	.004	.00	.003	3
Finding normality	0	.00	.00	.00	4
Total	1	.02	.22	.08	
Computing atomic weight					
From per cent of composition, M. W., and number of atoms	1	.01	.00	.01	1.5
From specific heat and atomic weights	1	.01	.00	.01	1.5
From weight of volume	1	.004	.00	.003	3.5
From M. W. and per cent composition	1	.004	.00	.003	3.5
From density and per cent composition	0	.00	.00	.00	6
From M. W. and atomic weight	0	.00	.00	.00	6
From per cent composition & one atomic Wt.	0	.00	.00	.00	6
Total	1	.03	.00	.02	

TABLE LXXVIII—*continued*

THE RANKING OF SUB-TYPES OF PROBLEMS FROM THE ANALYSIS OF THE COLLEGE ENTRANCE BOARD EXAMINATIONS AND FIVE SELECTED TEXTBOOKS

SUB-TYPE	No. of Texts Containing the Sub-Type	Per Cent of Total Space Devoted to the Sub-Type in the Five Texts	Per Cent of Total No. of College Entrance Board Questions	Weighted Average	Rank
Density of solids and liquids					
Finding density	2	.02	.00	.01	1.5
Finding weight	2	.01	.00	.01	1.5
Finding volume	1	.004	.00	.003	3
Total	3	.04	.00	.03	
Miscellaneous problems involving					
Number of molecules of water	0	.00	.06	.02	1
Finding length, shape changed, volume constant	1	.004	.00	.003	2
Finding weight of solvent	0	.00	.00	.00	6
Finding weight of air over given area	0	.00	.00	.00	6
Use of table	0	.00	.00	.00	6
Addition of weights	0	.00	.00	.00	6
Reduction of centigrade readings to Fahrenheit	0	.00	.00	.00	6
Reduction of centigrade readings to absolute	0	.00	.00	.00	6
Finding cost of composite, ratios, and price per ingredient given	0	.00	.00	.00	6
Total	1	.004	.06	.02	

TABLE LXXIX

TYPES OF ERROR IN FORM B, PART I, FOR THE 3-6 MONTH PERIOD

Number of Pupils, 276

No. of Q.	H_2		N_2		CO_2		He	
	Omissions	No. Wrong	Omissions	No. Wrong	Omissions	No. Wrong	Omissions	No. Wrong
1	0	3	13	41	11	78	25	65
2	0	13	14	67	13	127	27	83
3	0	30	13	148	13	54	22	50
4	1	2	14	37	14	31	19	29
5	1	31	14	163	14	46	18	57
6	3	121	21	107	19	76	31	85
7	4	60	26	96	22	86	31	109
8	4	140	29	121	25	83	45	147
9	11	78	42	108	39	99	57	119
10	17	70	43	91	32	91	55	74
Totals	41	548	229	979	202	771	330	818

Grand Total of Omissions 802

Number of Pupils Making the Omissions 75

Average Number of Omissions per Pupil 10.7

TABLE LXXX

TYPES OF ERROR IN FORM B, PART I, FOR THE 8-10 MONTH PERIOD

Number of Pupils, 308

No. of Q.	H_2		N_2		CO_2		He	
	Omissions	No. Wrong	Omissions	No. Wrong	Omissions	No. Wrong	Omissions	No. Wrong
1	0	2	8	41	7	52	22	51
2	1	14	10	76	12	107	33	83
3	3	22	11	155	18	69	29	72
4	5	13	18	46	22	31	31	42
5	2	29	17	169	21	58	27	74
6	5	174	16	115	18	84	36	94
7	5	77	17	132	23	96	38	100
8	6	187	29	146	27	88	48	144
9	16	88	32	101	33	128	62	130
10	14	52	30	64	29	83	50	79
Totals	57	658	188	1045	210	796	376	369

Grand Total of Omissions 831
Number of Pupils Making the Omissions 67
Average Number of Omissions per Pupil 12.4

TABLE LXXXI

TYPES OF ERROR IN FORM B, PART I, FOR THE 3-10 MONTH PERIOD

Number of Pupils, 584

No. of Q.	H_2		N_2		CO_2		He	
	Omissions	No. Wrong	Omissions	No. Wrong	Omissions	No. Wrong	Omissions	No. Wrong
1	0	5	21	82	18	130	47	116
2	1	27	24	143	25	234	60	166
3	3	52	24	303	31	123	51	122
4	6	15	32	83	36	62	50	71
5	3	60	31	332	35	104	45	131
6	8	295	37	222	37	160	67	179
7	9	137	43	228	45	182	69	209
8	10	327	58	267	52	171	93	291
9	27	166	74	209	72	227	119	249
10	31	122	73	155	61	174	105	153
Totals	98	1206	417	2024	412	1567	706	1687

Grand Total of Omissions 1633
Number of Pupils Making the Omissions 142
Average Number of Omissions per Pupil 11 5

TABLE LXXXII

Types of Error in Form B in Valence

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 276 No. Wrong	Sub-totals	% Wrong	% Sub-totals	8-10 Months No. of Pupils, 308 No. Wrong	Sub-totals	% Wrong	% Sub-totals	3-10 Months No. of Pupils, 584 No. Wrong	Sub-totals	% Wrong	% Sub-totals
1.	TOTALS	84		30.4		65		21.1		149		25.5	
	Omissions	37		13.4		29		9.4		66		11.3	
	$KC\ O_3$	15		5.4		2		.6		17		2.9	
	$K(CO_3)_2$	6		2.2		20		6.5		26		4.5	
	K_6CO_3	6		2.2		1		.3		7		1.2	
	Misc. Coef. and Valence		1		.4		3		1.0		4		.7
	$2KCO_3$		3		1.1		4		1.3		7		1.2
	$3K_3CO_3$		3		1.1		0		.0		3		.5
	Total Coef. and Valence	7		2.5		7		2.3		14		2.4	
	$K \div CO_3$	1		.4		0		.0		1		.2	
	(14 types) Misc.	12		4.3		6		1.9		18		3.1	
2.	TOTALS	147		53.3		105		34.1		252		43.1	
	Omissions	41		14.9		17		5.5		58		9.9	
	Al_2CO_3	40		14.5		28		9.1		68		11.6	
	Al_3CO_3	14		5.1		11		3.6		25		4.3	
	$Al(CO_3)_2$	9		3.3		20		6.5		29		5.0	
	$Al_2(CO_3)_2$	12		4.3		5		1.6		17		2.9	
	$Al(CO_2)_3$	5		1.8		6		1.9		11		1.9	
	$Al_3(CO_3)_2$	3		1.1		10		3.2		13		2.2	
	Misc. Coef. and Valence	8		2.9		4		1.3		12		2.1	
	(13 types) Misc.	15		5.4		4		1.3		19		3.3	
3.	TOTALS	84		30.4		81		26.3		165		28.3	
	Al_3PO_4	32		11.6		25		8.1		57		9.8	
	$Al_3(PO_4)_3$	11		4.0		25		8.1		36		6.2	
	Al_2PO_4	14		5.1		8		2.6		22		3.8	
	$Al(PO_4)_3$	6		2.2		7		2.3		13		2.2	
	Al_4PO_4	4		1.4		1		.3		5		.9	
	$Al(PO_4)_2$	2		.7		4		1.3		6		1.0	
	$Al_3(PO_4)_2$	2		.7		2		.6		4		.7	
	Misc. Coef. and Valence	3		1.1		1		.3		4		.7	
	$Al_3 \div PO_4$	2		.7		0		.0		2		.3	
	(10 types) Misc.	8		2.9		8		2.6		16		2.7	

TABLE LXXXII (*Continued*)

TYPES OF ERROR IN VALENCE IN FORM B

No. of Ques.	Types of Error	8-6 Months No. of Pupils, 276 No. Wrong	% Wrong	No. of Types	8-10 Months No. of Pupils, 308 No. Wrong	% Wrong	No. of Types	3-10 Months No. of Pupils, 584 No. Wrong	% Wrong
4.	Totals	171	62.0		167	54.2		338	57.9
	Omissions	42	15.2		18	5.8		60	10.3
	Cr_2O_6	43	15.6		14	20.8		107	18.3
	$Cr\ O_2$	17	6.2		20	6.5		37	6.3
	Cr_6O_2	7	2.5		14	4.5		21	3.6
	$Cr\ O_4$	16	5.8		10	3.2		26	4.5
	$3\ Cr_3 + O_2$	0	.0		1	.3		1	.2
	$Cr\ O_6$	5	1.8		7	2.3		12	2.1
	Cr_3O	3	1.1		6	1.9		9	1.5
	Cr_2O	7	2.5		6	1.9		13	2.2
	Cr_6O	6	2.2		3	1.0		9	1.5
	$Cr_6 + O_2$	1	.4		0	.0		1	.2
	Misc. Coef. and Valence	3	1.1		8	2.6		11	1.9
	(9 types) Miscellaneous	21	7.6	7	10	3.2	14	31	5.3
5.	Totals	178	64.5		155	50.3		333	57.0
	Omissions	99	35.9		72	23.4		171	29.3
	Not finished	7	2.5		2	.6		9	1.5
	1	5	1.8		5	1.6		10	1.7
	2	34	12.3		45	14.6		79	13.5
	3	12	4.3		9	2.9		21	3.6
	4	9	3.3		8	2.6		17	2.9
	5	6	2.2		9	2.9		15	2.6
	8	2	.7		0	.0		2	.3
	9	1	.4		0	.0		1	.2
	12	2	.7		2	.6		4	.7
	+ +	1	.4		0	.0		1	.2
	24	0	.0		1	.3		1	.2
	D_8C_2	0	.0		1	.3		1	.2
	D_2C_2	0	.0		1	.3		1	.2

TABLE LXXXIII

Types of Error in Nomenclature in Form B

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 276 No. Wrong	% Wrong	No. of Types	8-10 Months No. of Pupils, 308 No. Wrong	% Wrong	No. of Types	3-10 Months No. of Pupils, 584 No. Wrong	% Wrong
6.	Totals	136	49.3		95	30.8		231	39.6
	Omissions	30	10.9		17	5.5		47	8.0
	Hydrogen bromine	19	6.9		18	5.8		37	6.3
	Hypobromous acid	9	3.3		9	2.9		18	3.1
	Bromide	18	6.5		7	2.3		25	4.3
	Bromine	10	3.6		8	2.6		18	3.1
	Bromous acid	4	1.4		4	1.3		8	1.4
	Hybromous acid	0	.0		5	1.6		5	.9
	Bromic	3	1.1		3	1.0		6	1.0
	Hydrobromous	0	.0		3	1.0		3	.5
	Hydro bromic	4	1.4		0	.0		4	.7
	(29 types) Miscellaneous	39	14.1	18	21	6.8	41	60	10.3
7.	Totals	129	46.7		113	36.7		242	41.4
	Omissions	15	5.4		7	2.3		22	3.8
	Not finished	5	1.8		2	.6		7	1.2
	Manganese oxide	26	9.4		24	7.8		50	8.6
	Manganese dioxide	19	6.9		12	3.9		31	5.3
	Mangese dioxide	3	1.1		7	2.3		10	1.7
	Mercuric oxide	15	5.4		9	2.9		24	4.1
	Mercurous oxide	5	1.8		7	2.3		12	2.1
	Magnesium dioxide	8	2.9		2	.6		10	1.7
	Magnesium oxide	3	1.1		0	.0		3	.5
	Magnanese dioxide	5	1.8		0	.0		5	.9
	Magenese oxide	0	.0		15	4.9		15	2.6
	(19 types) Miscellaneous	25	9.1	18	28	9.1	36	53	9.1
8.	Totals	248	89.9		274	89.0		522	89 4
	Omissions	41	14.9		23	7.5		64	11.0
	Not finished	7	2.5		9	2.9		16	2.7
	Potassium chloride	32	11.6		39	12.7		71	12.2
	Potassium chlorate	105	38.0		159	51.6		264	45.2
	Potassium chlorite	14	5.1		12	3.9		26	4.5
	Potassium dichromate	5	1.8		1	.3		6	1.0
	Hydrochloric acid	4	1.4		0	.0		4	.7
	Potassium chloride oxide	0	1.0		4	1.3		4	.7
	Calcium chlorate	2	.7		0	.0		2	.3
	(33 types) Miscellaneous	38	13.8	22	27	8.8	48	65	11.1
9.	Totals	181	65.6		172	55.8		353	60.4
	Omissions	38	13.8		16	5.2		54	9.2
	Not finished	17	6.2		9	2.9		26	4.5
	Sodium nitrate	88	31.9		115	37.3		203	34.8
	Sodium nitride	4	1.4		6	1.9		10	1.7
	Sodium nitrous	3	1.1		3	1.0		6	1.0
	Sodium nitrous oxide	0	.0		3	1.0		3	.5
	Sodium nitric oxide	0	.0		4	1.3		4	.7
	Sodium nitrogen dioxide	0	.0		1	.3		1	.2
	Sodium sulphate	2	.7		0	.0		2	.3
	(26 types) Miscellaneous	29	10.5	12	15	4.9	38	44	7.5

TABLE LXXXIII (*Continued*)

TYPES OF ERROR IN NOMENCLATURE IN FORM B

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 276 No. Wrong	% Wrong	No. of Types	8-10 Months No. of Pupils, 308 No. Wrong	% Wrong	No. of Types	3-10 Months No. of Pupils, 584 No. Wrong	% Wrong
10.	Totals	162	58.7		143	46.4		305	52.2
	Omissions	53	19.2		26	8.4		79	13.5
	Not finished	13	4.7		20	6.5		33	5.7
	Sodium carbonate	22	8.0		24	7.8		46	7.9
	Sodium hydrocarbonate	7	2.5		34	11.0		41	7.0
	Sodium hydroxide	9	3.3		11	3.6		20	3.4
	Sodium chlorate	6	2.2		3	1.0		9	1.5
	Sodium carbonic acid	5	1.8		2	.6		7	1.2
	Hydrochloric acid	4	1.4		1	.3		5	.9
	Sodium chloride	4	1.4		0	.0		4	.7
	(36 types) Miscellaneous	39	14.1	20	22	7.1	51	61	10.4
11.	Totals	265	96.0		293	95.1		558	95.5
	Omissions	46	16.7		24	7.8		70	12.0
	Not finished	7	2.5		12	3.9		19	3.3
	Sodium bromide	88	31.9		93	30.2		181	31.0
	Sodium bromate	45	16.3		68	22.1		113	19.3
	Sodium bromite	27	9.8		19	6.2		46	7.9
	Sodium bromine	7	2.5		11	3.6		18	3.1
	Sodium bromine oxide	3	1.1		11	3.6		14	2.4
	Sodium bromoxide	4	1.4		4	1.3		8	1.4
	Sodium hypobromide	1	.4		4	1.3		5	.9
	Sodium hypobromous	1	.4		2	.6		3	.5
	(28 types) Miscellaneous	36	13.0	24	45	14.6	46	81	13.9

TABLE LXXXIV

Types of Error in Formulas in Form B

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 276				8-10 Months No. of Pupils, 308				3-10 Months No. of Pupils, 584			
		No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals
12.	TOTALS	156		49.3		78		25.3		214		36.6	
	Omissions	41		14.9		14		4.5		55		9.4	
	Not finished	23		8.3		10		3.2		33		5.7	
	Misc. Principle		12		4.3		5		1.6		17		2 9
	$K\ I\ O_2$		6		2.2		4		1.3		10		1.7
	$K\ I\ O$		16		5.8		15		4.9		31		5.3
	K_2O		0		.0		2		.6		2		.3
	Total Principle	34		12.3		26		8.4		60		10.3	
	Misc. Valence		8		2.9		2		.6		10		1.7
	$K\ I_2$		11		4.0		14		4.5		25		4.3
	Total Valence	19		6.9		16		5.2		35		6.0	
	Symbol	1		.4		4		1.3		5		.9	
	Symbol and Principle	11		4.0		1		.3		12		2.1	
	Symbol and Valence	0		.0		3		1.0		3		1.5	
	Valence and Principle	7		2.5		4		1.3		11		1.9	
13.	TOTALS	217		78.6		245		79.6		462		79.1	
	Omissions	34		12.3		15		4.9		49		8.4	
	Not finished	6		2.2		9		2.9		15		2.6	
	Misc. Principle		0		.0		1		.3		1		.2
	$Na\ Br\ O_4$		9		3.3		19		6.2		28		4.8
	$Na\ Br\ O_2$		10		3.6		14		4.5		24		4.1
	$Na\ Br\ O$		38		13.8		62		20.1		100		17.1
	$Na\ Br$		43		15.6		31		10.1		74		12.7
	Total Principle	100		36.2		127		41.2		227		38.9	
	Valence	2		.7		2		.6		4		.7	
	Symbol	0		.0		3		1.0		3		.5	
	Symbol and Principle	31		11.2		10		3.2		41		7.0	
	Misc. Prin. and Valence		17		6.2		35		11.4		52		8.9
	$Na\ Br_2$		15		5.4		33		10.7		48		8.2
	$Na\ Br_3$		12		4.3		11		3.6		23		3.9
	Total Principle and Val.	44		15.9		79		25.7		123		21.1	

TABLE LXXXIV (*Continued*)

TYPES OF ERROR IN FORMULAS IN FORM B

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 276				8-10 Months No. of Pupils, 308				3-10 Months No. of Pupils, 584			
		No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals
14.	TOTALS	206		74.6		214		69.5		420		71.9	
	Omissions	37		13.4		9		2.9		46		7.9	
	Not finished	9		3.3		6		1.9		15		2.6	
	Misc. Principles		21		7.6		16		5.2		37		6.3
	K_2SO_4		7		2.5		24		7.8		31		5.3
	Total Principle	28		10.1		40		13.0		68		11.6	
	Misc. Valence		1		.4		1		.3		2		.3
	K S O_3		34		12.3		54		17.5		88		15.1
	Total Valence	35		12.7		55		17.9		90		15.4	
	Symbol	1		.4		2		.6		3		.5	
	Symbol and Principle	20		7.2		16		5.2		36		6.2	
	Symbol and Valence	3		1.1		2		.6		5		.9	
	Misc. Prin. and Valence		21		7.6		38		12.3		59		10.1
	K SO_4		18		6.5		23		7.5		41		7.0
	K SO_2		18		6.5		23		7.5		41		7.0
	K S		16		5.8		0		.0		16		2.7
	Total Prin. and Valence	73		26.4		84		27.3		157		26.9	

TABLE LXXXIV (*Continued*)

TYPES OF ERROR IN FORMULAS IN FORM B

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 276				8-10 Months No. of Pupils, 308				3-10 Months No. of Pupils, 584			
		No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals
15.	TOTALS	190		68.8		176		57.1		366		62.7	
	Omissions	46		16.7		19		6.2		65		11.1	
	Not finished	2		.7		4		1.3		6		1.0	
	Misc. Principles		8		2.9		4		1.3		12		2.1
	Fe H_2O		13		4.7		0		.0		13		2.2
	Fe OH_2		1		.4		2		.6		3		.5
	Total Principle	22		8.0		6		1.9		28		4.8	
	Misc. Valence		18		6.5		39		12.7		57		9.8
	Fe OH		41		14.9		39		12.7		80		13.7
	Fe $(OH)_3$		18		6.5		27		8.8		45		7.7
	Total Valence	77		27.9		105		34.1		182		31.2	
	Symbol	0		.0		2		.6		2		.3	
	Symbol and Principle	9		3.3		3		1.0		12		2.1	
	Symbol and Valence	3		1.1		2		.6		5		.9	
	Principle and Valence	27		9.8		27		8.8		54		9.2	
	Oxides	4		1.4		8		2.6		12		2.1	
16.	TOTALS	230		83.3		240		77.9		470		80.5	
	Omissions	93		33.7		66		21.4		159		27.2	
	Not finished	4		1.4		5		1.6		9		1.5	
	Misc. Principle		15		5.4		15		4.9		30		5.1
	H Br O_4		13		4.7		9		2.9		22		3.8
	H Br O_3		6		2.2		8		2.6		14		2.4
	H Br O_2		24		8.7		31		10.1		55		9.4
	H Br		29		10.5		43		14.0		72		12.3
	Total Principle	87		31.5		106		34.4		193		33.0	
	Valence	4		1.4		2		.6		6		1.0	
	Symbol	4		1.4		5		1.6		9		1.5	
	Symbol and Principle	20		7.2		12		3.9		32		5.5	
	Misc. Principle and Val.		15		5.4		34		11.0		49		8.4
	H2Br O3		3		1.1		10		3.2		13		2.2
	Total Prin. and Valence	18		6.5		44		14.3		62		10.6	

TABLE LXXXIV (*Continued*)

TYPES OF ERROR IN FORMULAS IN FORM B

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 276				8-10 Months No. of Pupils, 308				3-10 Months No. of Pupils, 584			
		No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals
17.	TOTALS	268		97.1		280		90.9		548		93.8	
	Omissions	112		40.6		71		23.1		183		31.3	
	Not finished	56		20.3		67		21.8		123		21.1	
	Misc. Principles		13		4.7		15		4.9		28		4.8
	$K_2Cr\ O_3$		4		1.4		1		.3		5		.9
	$K_2Cr\ O_4$		2		.7		1		.3		3		.5
	Total Principles	19		6.9		17		5.5		36		6.2	
	Valence	4		1.4		1		.3		5		.9	
	Symbol	18		6.5		1		.3		19		3.3	
	Misc. Symbol and Prin.		23		8.3		39		12.7		61		10.4
	$K\ ClO_2$		8		2.9		3		1.0		11		1.9
	Total Symbol and Prin.	30		10.9		42		13.6		72		12.3	
	Misc. Principle and Val.		19		6.9		42		13.6		61		10.4
	$K\ Cr\ O_4$		1		.4		7		2.3		8		1.4
	$K\ Cr\ O_2$		0		.0		12		3.9		12		2.1
	$K\ Cr_2$		9		3.3		20		6.5		29		5.0
	Total Prin. and Valence	29		10.5		81		26.3		110		18.8	

TABLE LXXXV

Types of Error in Equations in Form B

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 276				8-10 Months No. of Pupils, 308				3-10 Months No. of Pupils, 584			
		No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals
18.	TOTALS	84		30.4		71		23.1		155		28.5	
	Omissions	30		10.9		21		6.8		51		8.7	
	Balance	36		13.0		25		8.1		61		10.4	
	Formula	18		6.5		25		8.1		43		7.4	
19.	TOTALS	109		39.5		84		27.3		193		33.0	
	Omissions	32		11.6		36		11.7		68		11.6	
	Balance	51		18.5		28		9.1		79		13.5	
	Formula	26		9.4		20		6.5		46		7.9	
20.	TOTALS	122		44.2		100		32.5		222		38.0	
	Omissions	60		21.7		55		17.9		115		19.7	
	Balance	55		19.9		35		11.4		90		15.4	
	Formula	7		2.5		10		3.2		17		2.9	
21.	TOTALS	125		45.3		99		32.1		224		38.4	
	Omissions	31		11.2		21		6.8		52		8.9	
	Not finished	2		.7		1		.3		3		.5	
	Balance	12		4.3		18		5.8		30		5.1	
	Valence	28		10.1		25		8.1		53		9.1	
	Misc. Formula		46		16.7		24		7.8		70		12.0
	H_2Cl_2		1		.4		2		.6		3		.5
	Total Formula	47		17.0		26		8.4		73		12.5	
	Product	5		1.8		8		2.6		13		2.2	
22.	TOTALS	219		79.3		219		71.1		438		75.0	
	Omissions	46		16.7		29		9.4		75		12.8	
	Not Finished	1		.4		5		1.6		6		1.0	
	Balance	15		5.4		16		5.2		31		5.3	
	Valence	36		49.3		154		50.0		290		49.7	
	Formula	16		5.8		13		4.2		29		5.0	
	Product	2		.7		2		.6		4		.7	
	Extra product	2		.7		0		.0		2		.3	
	$Fe_2(NO_3)_6$	1		.4		0		.0		1		.2	

TABLE LXXXV (*Continued*)

TYPE OF ERROR IN EQUATIONS IN FORM B

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 276				8-10 Months No. of Pupils, 308				3-10 Months No. of Pupils, 584			
		No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals
25.	TOTALS	185		67.0		178		57.8		363		62.2	
	Omissions	65		23.5		63		20.5		128		21.9	
	Molecular	102		37.0		106		34.4		208		35.6	
	Balance	7		2.5		3		1.0		10		1.7	
	Valence	0		.0		0		.0		0		.0	
	Formula	10		3.6		3		1.0		13		2.2	
	Product	1		.4		0		.0		1		.2	
	Ex. Product	0		.0		1		.3		1		.2	
	Wts. Only	0		.0		2		.6		2		.3	
26.	TOTALS	175		63.4		159		51.6		334		57.2	
	Omissions	87		31.5		67		21.8		154		26.4	
	Molecular Ca		12		4.3		6		1.9		18		3.1
	Molecular H		34		12.3		34		11.0		68		11.6
	Molecular Ca & H		0		.0		6		1.9		6		1.0
	Total Molecular	46		16.7		46		14.9		92		15.8	
	Balance	38		13.8		39		12.7		77		13.2	
	Product	1		.4		5		1.6		6		1.0	
	Formula	3		1.1		2		.6		5		.9	
27.	TOTALS	109		39.5		96		31.8		207		35.4	
	Omissions	58		21.0		48		15.6		106		18.2	
	Molecular Zn		1		.4		2		.6		3		.6
	Molecular H		4		1.4		9		2.9		13		2.2
	Total Molecular	5		1.8		11		3.6		16		2.7	
	Balance	10		3.6		5		1.6		15		2.6	
	Valence	9		3.3		13		4.2		22		3.8	
	Formula	3		1.1		0		.0		3		.5	
	Product	24		8.7		21		6.8		45		7.7	

TABLE LXXXV (*Continued*)

TYPES OF ERROR IN EQUATIONS IN FORM B

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 276				8-10 Months No. of Pupils, 308				3-10 Months No. of Pupils, 584			
		No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals
28.	TOTALS	199		72.1		157		51.0		356		61.0	
	Omissions	73		26.4		64		20.8		137		23.5	
	Not finished	2		.7		4		1.3		6		1.0	
	Balance	11		4.0		14		4.5		25		4.3	
	Valence	78		28.3		55		17.9		133		22.8	
	Product	24		8.7		15		4.9		39		6.7	
	Formula	11		4.0		5		1.6		15		2.7	
39.	TOTALS	234		84.8		224		72.7		458		78.4	
	Omissions	148		53.6		140		45.5		288		49.3	
	Not finished	17		6.2		14		4.5		31		5.3	
	Balance	1		.4		9		2.9		10		1.7	
	Valence	30		10.9		24		7.8		54		9.2	
	Misc. Formula		36		13.3		32		10.4		68		11.6
	Na Na		1		.4		0		.0		1		.2
	Total Formula	37		13.4		32		10.4		69		11.8	
	Product	2		.4		5		1.6		6		1.0	
40.	TOTALS	257		93.1		235		76.3		492		84.2	
	Omissions	192		69.6		156		50.7		348		59.6	
	Not finished	16		5.8		10		3.2		26		4.5	
	Balance	4		1.4		10		3.2		14		2.4	
	Valence	7		2.5		21		6.8		28		4.8	
	Misc. Formula		35		12.7		35		11.4		70		12.0
	Ca H N O_3		1		.4		0		.0		1		.2
	Total Formula	36		13.0		35		11.4		71		12.2	
	Product	2		.7		3		1.0		5		.9	

TABLE LXXXVI

Types of Error in Ions in Form B

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 276				8-10 Months No. of Pupils, 308				3-10 Months No. of Pupils, 584			
		No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals
31.	TOTALS	194		70.3		180		58.4		374		64.0	
	Omissions	122		34.2		89		28.9		211		36.1	
	Principle	9		3.3		14		4 5		23		3.9	
	Numbers only	3		1.1		5		1.6		8		1.4	
	Misc. signs only		2		.7		12		3.9		14		2.4
	+, −		19		6.9		21		6 8		40		6.8
	Total signs only	21		7.6		33		10.7		54		9.2	
	H, Cl	10		3.6		9		2.9		19		3.3	
	Hydrogen, chlorine	12		4.3		8		2.6		20		3.4	
	Signs reversed and Val.	2		.7		3		1.0		5		.9	
	Signs reversed	2		.7		5		1.6		7		1.2	
	Miscellaneous	3		1.1		6		1.9		9		1.5	
	Valence	10		3.6		8		2.6		18		3.1	
32.	TOTALS	253		91.7		280		90.9		533		91.3	
	Omissions	130		47.1		112		36.4		242		41.4	
	Principle	32		11.6		24		7.8		56		9.6	
	Misc. signs only		15		5.4		22		7.1		37		6.3
	+ +, − −		2		.7		5		1.6		7		1.2
	Total signs only	17		6.2		27		8.8		44		7.5	
	Numbers only	4		1.4		5		1.6		9		1.5	
	Miscellaneous	13		4.7		25		8.1		38		6.5	
	Valence	22		8.0		11		3.6		33		5.7	
	Na + +		9		3.3		22		7.1		31		5.3
	Na $+_2$		3		1.1		5		1.6		8		1.4
	Na_2+ +		7		2.5		15		4.9		22		3.8
	Na+		12		4.3		29		9.4		41		7.0
	2 Na + +		1		.4		2		.6		3		.5
	Total Na	32		11.6		73		23.7		105		18.0	
	Sodium sulphate	3		1.1		3		1.0		6		1.0	

TABLE LXXXVI (*Continued*)

TYPES OF ERROR IN IONS IN FORM B

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 276				8-10 Months No. of Pupils, 308				3-10 Months No. of Pupils, 584			
		No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals
33.	TOTALS	274		99.3		299		97.1		573		98.1	
	Omissions	116		42.0		89		28.9		205		35.1	
	Not finished	14		5.1		16		5.2		30		5.1	
	Principle	95		34.4		113		36.7		208		35.6	
	Precipitate ionized	44		16.0		72		23.4		116		19.9	
	No Ions on the right	1		.4		3		1.0		4		.7	
	No Ions on the left	1		.4		1		.3		2		.3	
	Miscellaneous	3		1.1		5		1.6		8		1.4	

TABLE LXXXVII

Types of Error in Problems in Form B

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 276				8-10 Months No. of Pupils, 308				3-10 Months No. of Pupils, 584			
		No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals
23.	TOTALS	202		73.2		210		68.2		412		70.5	
	Omissions	95		34.4		69		22.4		164		28.1	
	Not Finished	2		.7		7		2.3		9		1.5	
	Misc. Principle		43		15.6		41		13.3		84		14.4
	Proportion		5		1.8		2		.6		7		1.2
	Total Principle	48		17.4		43		14.0		91		15.6	
	Misc. Mechanics		8		2.9		10		3.2		18		3.1
	Multiplication		4		1.4		14		4.5		18		3.1
	Division		6		2.2		7		2.3		13		2.2
	Total Mechanics	18		6.5		31		10.1		49		8.4	
	Molecular Weight	39		14.1		60		19.5		99		17.0	
24.	TOTALS	240		87.0		247		80.2		487		83.4	
	Omissions	97		35.1		93		30.2		190		32.5	
	Not Finished	0		.0		2		.6		2		.3	
	Misc. Principle		58		21.0		62		20.1		120		20.5
	M. W. = Answer		45		16.3		38		12.3		83		14.2
	22.4 1 = Answer		7		2.5		12		3.9		19		3.3
	.09 x M.W..		4		1.4		1		.3		5		.9
	22.4 x M.W.		9		3.3		14		4.5		23		3.9
	M.W. ÷ .09		7		2.5		1		.3		8		1.4
	Total Principle	130		47.1		128		41.6		258		44.2	
	Misc. Mechanics		4		1.4		6		1.9		10		1.7
	Division		4		1.4		9		2.9		13		2.2
	Total Mechanics	8		2.9		15		4.9		23		3.9	
	Molecular Weight	5		1.8		9		2.9		14		2.4	

TABLE LXXXVII (*Continued*)

TYPES OF ERROR IN PROBLEMS IN FORM B

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 276				8-10 Months No. of Pupils, 308				3-10 Months No. of Pupils, 584			
		No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals
29.	TOTALS	237		85.9		216		70.1		453		77.6	
	Omissions	116		42.0		141		45.8		301		51.5	
	Not Finished	2		.7		4		1.3		6		1.0	
	Misc. Principle		43		15.6		41		13.3		84		14.4
	L and M.W.		20		7.2		23		7.5		43		7.4
	M. W., L., and 22.4		3		1.1		0		.0		3		.5
	Total Principle	66		23.9		64		20.8		130		22.3	
	Misc. Mechanics		7		2.5		4		1.3		11		1.9
	Division		2		.7		3		1.0		5		.9
	Total Mechanics	9		3.3		7		2.3		16		2.7	
30.	TOTALS	228		82.6		243		78.9		471		80.6	
	Omissions	149		54.0		155		50.3		304		52.1	
	Not Finished	1		.4		1		.3		2		.3	
	Misc. Principle		28		10.1		23		7.5		51		8.7
	Direct Proportion		41		14.9		56		18.2		97		16.6
	Total Principle	69		25.0		79		25.7		148		25.3	
	Misc. Mechanics		7		2.5		5		1.6		12		2.1
	Decimals		2		.7		3		1.0		5		.9
	Total Mechanics	9		3.3		8		2.6		17		2.9	

TABLE LXXXVII (*Continued*)

TYPES OF ERROR IN PROBLEMS IN FORM B

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 276				8-10 Months No. of Pupils, 308				3-10 Months No. of Pupils, 584			
		No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals	No. Wrong	Sub-totals	% Wrong	% Sub-totals
38.	TOTALS	235		85.1		227		73.7		462		79.1	
	Omissions	145		52.5		140		45.5		285		48.8	
	Not Finished	4		1.4		0		.0		4		.7	
	Misc. Principle		42		15.2		50		16.2		92		15.8
	At. Wt. ÷ %		3		1.1		3		1.0		6		.6
	% ÷ %		2		.7		2		.6		4		.7
	% x M.W.		1		.4		3		1.0		4		.7
	CH_3 = Answer		9		3.3		10		3.2		19		3.3
	C_3H = Answer		16		5.8		13		4.2		29		5.0
	C_1H = Answer		3		1.1		1		.3		4		.7
	Total Principle	76		27.5		82		26.6		158		27.1	
	Misc. Mechanics		6		2.2		1		.3		7		1.2
	Division		4		1.4		4		1.3		8		1.4
	Total Mechanics	10		3.6		5		1.6		15		2.6	

TABLE LXXXVIII

Types of Error in Laws in Form B

No. of Ques.	Types of Error	3-6 Months No. of Pupils, 276 No. Wrong	Sub-totals	% Wrong	% Sub-totals	8-10 Months No. of Pupils, 308 No. Wrong	Sub-totals	% Wrong	% Sub-totals	3-10 Months No. of Pupils, 584 No. Wrong	Sub-totals	% Wrong	% Sub-totals
34.	TOTALS	148		53.6		120		39.0		268		45.9	
	Omissions	52		18.8		40		13.0		92		15.8	
	1	49		17.8		54		17.5		103		17.6	
	2	35		12.7		22		7.1		57		9.8	
	3	4		1.4		0		.0		4		.7	
	4	8		2 9		3		1.0		11		1.9	
	2 and 5	0		0.0		1		.3		1		.2	
35.	TOTALS	158		57.2		175		56.8		333		57.0	
	Omissions	38		13.8		40		13.0		78		13.4	
	1	11		4.0		17		5.5		28		4.8	
	3	55		19.9		59		19.2		114		19.5	
	4	37		13.4		34		11.0		71		12.2	
	5	17		6.2		25		8.1		42		7.2	
36.	TOTALS	168		60.9		180		58.4		348		59.6	
	Omissions	50		18.1		36		11.7		86		14.7	
	1	15		5.4		6		1.9		21		3.6	
	3	67		24.3		85		27.6		152		26.0	
	4	3		1.1		3		1.0		6		1.0	
	5	20		7.2		49		15.9		69		11.8	
	3 and 4		8		2.9		0		0		8		1.4
	2 and 5		2		.7		0		0		2		.3
	3 and 5		1		.4		0		0		1		.2
	2 and 3		1		.4		1		.3		2		.3
	1 and 2		1		.4		0		0		1		.2
	Total of 2 underscored	13		4.7		1		.3		14		2.4	
37.	TOTALS	206		74.6		223		72.4		429		73.5	
	Omissions	43		15.6		38		12.3		81		13.9	
	1	99		35.9		125		40.6		224		38.4	
	3	46		16.7		46		14.9		92		15.8	
	4	16		5.8		14		4.5		30		5.1	
	5	0		0.0			0		0		1		.2
	1 and 4		1		.4	0		.0		0		.0	
	1, 2, & 3		1		.4		0		0		1		.2
	Total of 2 or more underscored	2		.7		0		.0		2		.3	

CORRELATIONS

Since the investigator made no attempt to scale and standardize these diagnostic tests, no evidence has been placed in the body of this thesis to show their reliability. Correlations to determine reliability were calculated, however, and are presented at this point for those who may be interested in correlations for an unstandardized test. They are as follows:

Final Marks and Form B	+ .624	± .083	for 24 cases
Final Marks and Form A	+ .551	± .069	for 46 cases
Form A and Form B (3-10 Mos.)	+ .720	± .015	for 430 cases
Form A (3-6 Mos..) and Form B (8-10 Mos.)	+ .783	± .016	for 269 cases
Farm A (8-10 Mos.) and Form B (3-6 Mos.)	+ .767	± .033	for 160 cases
Even and Odd Items in Form A (3-10 Mos.	+ .856	± .002	for 624 cases
Even and Odd Items in Form B (3-10 Mos.)	+ .868	± .007	for 584 cases
Part I and Part II in Form A (3-10 Mos.)	+ .450	± .021	for 624 cases
Part I and Part II in Form B (3-10 Mos.)	+ .533	± .020	for 584 cases
Part I, Form A (8-10 Mos.) and Part I. Form B (3-6 Mos.)	+ .481	± .040	for 160 cases
Part I, Form A (3-6 Mos.) and Part I, Form B (8-10 Mos.)	+ .581	± .027	for 269 cases
Part II, Form A (3-6 Mos.) and Part II, Form B (8-10 Mos.)	+ .786	± .016	for 269 cases
Part II, Form A (8-10 Mos.) and Part II, Form B (3-6 Mos.)	+ .748	± .023	for 160 cases

The correlations between the different forms of the test and the final chemistry grades were computed from the data furnished by one school. The probable error for each of these correlations signifies that the correlation figures are reliable since the correlations are more than three or six times the probable error.

The correlations of .720 for 430 cases represents a correlation for all pupils who took both the A and B forms. This correlation figure is not as high as it should be since one half of the group took Form A the first time and the other half Form B the first time. Had all taken Form A the first time and then taken Form B the second time, the correlation would have yielded a higher figure. In order to determine to what degree the correlation was affected by this factor, correlations were calculated for those who took Form A first and then Form B and for those who took Form B first and then Form A. The correlations for each were .783 and .767 which are higher correlations than the correlation for 430 cases.

Another indication of the reliability of the tests is shown in the high correlation which exist between the odd and even numbered items in each form. These correlations of .856 and .868 represent the highest correlations in the whole series which were cmputed. The correlations between Parts I and II for Form A is .45 while that for Form B is .533. The fact that the nature of the material in Part I is so vastly different from that in Part II very likely accounts for these rather low correlations. The reasoning factor plays a more important part in Part II than in Part I, while in Part I the memory factor is predominant. When Part I of Form A is correlated with Part I of Form B and when Part II of Form A is correlated with Part II of Form B, the correlation for Part II yields a higher and more significant figure than that for Part I.

DIRECTIONS FOR ADMINSTERING THE TESTS

Distribute the tests with instructions not to turn any pages nor begin any work until the signal is given. Make sure that all pupils are provided with sharpened pencils. Have a supply of sharpened pencils on hand. When all are ready, explain briefly to the pupils that you want to see how many of the questions in the test they can answer. Then have the pupils fill in the blanks on the first sheet. Explain the meaning of "age" in "years" and "months", also "Total number of months you have studied chemistry." When the blanks have been filled in, have the pupils read the directions silently as you read them aloud.

Then say "Ready — Go." At the end of thirty-seven minutes, "Stop." Collect all papers at once. Answer no questions during the test.

Directions for Scoring

Use a colored pencil for marking the papers. In correcting the questions on the first page of the test, place a check mark in each blank where the answer is wrong or omitted, being careful not to obscure the pupil's mark. At the right of the last space of each horizontal line set down the number of correct

responses. Score the vertical column in the same manner and place the score at the foot of each column. If the counting of scores has been correct the sum of the vertical scores will equal the sum of the horizontal scores. Place this sum in the blank marked "score."

In scoring Part II, draw a line through the number of the question wherever the answer is wrong or omitted. Use no marks where the answers are correct. Do not accept the answer as correct unless it agrees with the answer or answers given in the key. Under no consideration give part credit. The score for Part II is the number of questions right.

The total score for the test is equal of the sum of the scores for Parts I and II. Place these scores in the proper blanks on the cover page of the test.

The author will appreciate any further data such as mental ages, intelligence quotients, intelligence test scores, and scores made on standard chemistry tests.

Time of Giving the Tests

These tests can be given about the middle of the year or at any time after that. When both forms of the test are used, the first can be used to analyze the pupils' difficulties and the second, to determine the effect of remedial measures.

Uses of the Tests

Since the function of this test is diagnostic, no attempt is being made to standardize it although enough data will be collected to test its reliability. Therefore the raw scores of Parts I and II are accepted as computed without their being translated into terms of true scores.

This test has been designed to diagnose the pupils' difficulties in the "mechanics" of chemistry. The writer interprets the term "mechanics" to include properties of gases, the principle of writing formulas, the principle of naming formulas, the principle of writing equations, the principles involved in the solving of chemical problems, and an understanding of the principal laws of chemistry. It is therefore the function of this

test to diagnose student difficulties in mechanics of chemistry and not subject matter nor laboratory practices.

The use of this test should show the teacher whether the pupils have a clear conception of the properties of gases, and whether they can discriminate in the case of such terms as "supporting combustion" and "burning in air." The scores at the end of the horizontal rows will indicate which properties have proven most difficult, while the scores at the bottom of the vertical columns will indicate the pupils' degree of familiarity with the properties of a given gas. If the class or if individuals have a poor conception of the properties of gases, the teacher can remedy this weakness by the use of proper demonstration or individual laboratory experiments on gases.

The pupils' abilities to name and write formulas will be diagnosed by the 17 questions on page 2 of the test. The pupils' difficulties will be in one or more of the following categories:

1. Lack of knowledge of the principle of writing formulas with valence given.

2. Lack of knowledge of the principle of naming and writing formulas when the fundamental name and formula are given.

3. Failure to remember the fundamental formula and name.

When the teacher knows wherein the pupils are weak in this phase of the mechanics of chemistry, he can apply the necessary remedial measures.

The diagnosis in the case of equations involves the following steps:

1. Balancing equations.

2. Completion of equations where metals or metal radicals exchange places with the acid radicals. (Double decomposition)

3. Writing entire equations with no formulas given.

4. Writing ionic equations.

Weakness in any one of the several types of equations will indicate where drill work will prove most effective.

The time element in the test permits the use of but four simple chemical problems. Each of the problems is an application of one of the laws presented in the multi-choice

questions. It will be helpful to the teacher to know whether wrong answers to the problems are due to lack of knowledge of the priciple or to a mechanical error in the calculations. Both of these weaknesses can be remedied by placing proper emphasis on the principle of the problem or on accuracy in solving problems.

A comparison of the percentages of the class answering two of the four questions on laws correctly with the percentages of the corresponding chemical problems should prove illuminating.

By calculating the number of pupils answering each question correctly or by calculating the percentage of the class answering each question correctly, the teacher will know just what material in the mechanics of chemistry will require the greater teaching emphasis.

PART I OF PRELIMINARY TEST

Last Name .....

Sample:	1	2	3	4	5	6	7	8	9	10
Helium	x	x	0	0	x	0	0	x	0	0

These 10 properties represent the possible answers to the 9 gases whose formulas are listed below the directions.

1. Colorless
2. Odorless
3. Heavier than air
4. Same weight as air
5. Lighter than air
6. Supports Combustion
7. Burns in air
8. A lighted stick thrust into the gas goes out.
9. The gas is so soluble in water that it is not collected over water.
10. The gas when moist has bleaching properties.

Directions: The 10 numbers at the top of the columns represent the numbers of the 10 answers. Place a cross (x) in each space where the answer is true and a cipher (0) if the answer is false. Leave a blank where you do not know the answer. In the sample question at the top of the page, answers

1, 2, 5, and 8 are true and therefore are marked with crosses. The weight of one liter of air is 1.293 grams. The necessary atomic weights are given here:

O 16; C 12; A 40; H 1; N 14; S 32.

	1	2	3	4	5	6	7	8	9	10
1. O_2										
2. H_2										
3. Cl_2										
4. A										
5. CO_2										
6. NO										
7. NO_2										
8. C_2H_2										
9. SO_2										

Score.....

CHEMISTRY TEST. FORM A. (Unrevised)

Part I

Last Name.....

Directions: In the following exercises, the formulas of 9 gases are listed at the top of each column and the properties of the gases are listed on the left. Place a cross (x) in each space where the property is the true answer and a cipher (0) where the property is a false answer. Leave a blank where you do not know the answer. In the case of each gas, start at the top

and work down the column. The weight of one liter of air is 1.293 grams. The necessary atomic weights are given here:

O 16; A 40; H 1; N 14.

Sample:	He
1. Colorless	x
2. Odorless	x
3. Heavier than air	o
4. Same weight as air	o
5. Lighter than air	x

	O_2	H_2	Cl_2	NO_2	A
1. Colorless					
2. Odorless					
3. Heavier than air					
4. Same weight as air					
5. Lighter than air					
6. Supports combustion					
7. Burns in air					
8. A lighted stick thrust into it goes out.					
9. The gas is so soluble in water that it cannot be collected over water.					
10. The gas when moist bleaches.					

Part II

Last Name .....

In the exercises below, the valence to be used is as indicated in the following elements and radicals:

Na^+; Ca^{++}; Al^{+++}; Mn^{++++}; NO_3^-; O^{--}; PO_4^{---}.

Insert subscripts where necessary to make the following formulas correct. Do nothing to those already written correctly. Sample: $NaPO_4$. The figure 3 when placed under the Na gives as the correct formula Na_3PO_4.

1. NaO; 2. Al (NO_3); 3. Ca (PO_4); 4. MnO; 5. If in the list of generalized chemical formulas given below, A has a valence of 3, what is the valence of D?

A_2B_3; CB_2; CD_2. .....

Write the chemical name of the compound after each of the following formulas:

Sample: $HClO_3$ Chloric Acid.

6. HCl .....
7. $HClO_4$ .....
8. Na ClO .....
9. K_2O .....
10. K_2SO_3 .....
11. Na_2S .....
12. C_2H_5OH .....
13. $KHSO_4$ .....

Write the formula after each of the following names:

Sample: Chloric acid $HClO_3$

14. Sodium perchlorate .....
15. Hypochlorous acid .....
16. Sodium bromide .....
17. Sodium nitrite .....
18. Hydrosulphuric acid .....
19. Ammonium carbonate .....
20. Ferric hydroxide .....
21. Acetic acid .....

Last Name .....

Balance the following equations. If they are correct do nothing to them.

Sample: $AgNO_3 + CaCl_2 = \underline{AgCl} + Ca(NO_3)_2$

When the correct numbers are placed before the proper formulas, the equation is balanced correctly. Thus, $2AgNO_3 + CaCl_2 = 2AgCl + Ca(NO_3)_2$ represents the former equation properly balanced.

22. $AlCl_3 + NaOH = \underline{Al(OH)_3} + NaCl.$

23. $AlCl_3 + Ca(OH)_2 = CaCl_2 + \underline{Al(OH)_3}$

24. $Pb(NO_3)_2 + H_2SO_4 = \underline{PbSO_4} + HNO_3$

Complete and balance each of the following equations:

Sample: $AgNO_3 + BaCl_2 =$

When completed and balanced the above equation reads $2AgNO_3 + BaCl_2 = 2AgCl + Ba(NO_3)_2$

In each of the following cases, the metals or metal radicals exchange places with the acid radicals as shown in the sample.

25. $FeSO_4 + NH_4OH =$ .....

26. $Al_2(SO_4)_3 + Ba(NO_3)_2 =$ .....

27. From the following equation, calculate how many grams of Na_2SO_3 will be required to produce 192 grams of SO_2.

$Na_2SO_3 + H_2SO_4 = Na_2SO_4 + SO_2 + H_2O$

(Atomic weights: Na 23; S 32; O 16; H 1.)

Put answer here.....

Last Name .....

28. The weight of one liter of SO_2 is .....grams. (The necessary atomic weights are given in problem 27)

Complete and balance the following equations using correct molecular formulas in each reaction.

29. $Zn + HCl =$ .....

30. $KClO_3$ (heated) = ...

31. $NaHCO_3$ (heated) = ...

32. $(NH_4)_2 SO_4 + NaOH =$ .....

33. How many liters of oxygen are required to burn 20 liters of CO ?

34. If there are 40 liters of gas at 127 degrees centigrade, how many liters are there at 27 degrees centigrade, the pressure remaining constant? .....

In the following questions, only one answer to each question is correct. Underline the correct answer.

Sample: An alloy is: 1. an element; 2. a compound; 3. a radical; 4. a mixture; 5. an ion.

Last Name .....

35. The fact that 20 grams of mercury will unite with 1.6 grams of oxygen to form 21.6 grams of mercuric oxide illustrates the law of:

1. multiple proportions; 2. conservation of matter; 3. Henry; 4. Charles; 5. Avogadro.

36. The pressure remaining constant, the volumes of ga es vary:

1. directly as the temperature; 2. inversely as the tempe ature; 3. directly as the absolute temperature; 4. inversely as the absolute temperature; 5. directly as the centigrade ter perature.

37. The fact that water always contains 11.18% of hydrogen by weight illustrates the law of:

1. Gay Lussac; 2. definite proportions; 3. multiple proportions; 4. Henry; 5. Berthollet.

38. According to the theory of ionization, a base is a compound which when dissolved in water produces:

1. hydrogen ions; 2. NO_3 ions; 3. OH ions; 4. hydrogen molecules; 5. OH molecules.

39. The fact that 3 liters of hydrogen will unite with one liter of nitrogen to form 2 liters of ammonia gas illustrates the law of:

1. Boyle; 2. Gay Lussac; 3. periods; 4. definite proportions; 5. multiple proportions.

40. Determine the simple formula of a compound composed of carbon 85.71% and hydrogen 14.28%. (At. Wts.: C 12; H 1.) .....

Last Name .....

Write the entire equation for the following reactions using correct molecular formulas in each case.

41. The action of quick or burnt lime on water.....

.....

42. The action of hydrochloric acid on limestone or marble. .....

43. The preparation of hydrogen chloride from sulphuric acid and one other compound. .....

Write the following reactions as complete ionic equations properly balanced.

44. Silver nitrate plus hydrochloric acid.

.....

45. Sulphuric acid plus sodium hydroxide.

.....

CHEMISTRY TEST—Form A.

Part I.

Last Name .....

DIRECTIONS: In the following exercises the formulas of 5 gases are listed at the top of each column and the properties of the gases are listed on the left. Place a cross (x) in each space where the property is the true answer and a cipher (0) where the property is a false answer. Leave a blank where you do not know the answer. In the case of each gas start at the top and work down the column, as shown in the case of the first column marked He, which is already marked for you. The weight of one liter of air is 1.293 grams. The necessary atomic weights are given here:

He 4; O 16; Cl 35.5; C 12; A 40.

	He	O_2	C_2	CO	A
1. Colorless	X				
2. Odorless	X				
3. Heavier than air	O				
4. Same weight as air	O				
5. Lighter than air	X				
6. Supports combustion	O				
7. Burns in air	O				
8. A lighted stick thrust into it goes out	X				
9. The gas is so soluble in water that it cannot be collected over water	O				
10. The gas when moist bleaches	O				

Score.....

WHEN THROUGH TURN IMMEDIATELY TO PAGE 2

Part II

Last Name .....

In the exercise below, the valence to be used is as indicated for the following elements and radicals:
Na^+; Ca^{++}; Al^{+++}; Mn^{++++}; NO_3^-; O^{--}; PO_4^{---}

Insert subscripts where necessary to make the following formulas correct:

Sample

$NaPO_4$. The figure 3 when placed under the Na gives the correct formula Na_3PO_4

1. NaO
2. Al (NO_3)
3. Ca (PO_4)
4. MnO
5. If in the list of generalized chemical formulas given below, A has a valance of 3, what is the valence of D?

A_2B_3; CB_2; CD_2. .....

Write the chemical name of the compound after each of the following formulas:

Sample

$HClO_3$	Chloric Acid

6. HCl.....
7. K_2O .....
8. Na_2S .....
9. K_2SO_3 .....
10. $KHSO_4$ .....
11. NaClO .....

TURN IMMEDIATELY TO PAGE 3

Last Name .....

Write formulas after each of the following names:

Sample

Chloric Acid $HClO_3$

12. Sodium bromide .....
13. Ferric hydroxide .....
14. Sodium nitrate .....
15. Ammonium carbonate .....
16. Hypochlorous Acid .....
17. Sodium perchlorate .....

Balance the following equations:

Sample

$AgNO_3 + CaCl_2 = AgCl + Ca(NO_3)_2$

When the correct numbers are placed before the proper formulas, the equation is balanced correctly.
Thus, $2AgNO_3 + CaCl_2 = 2AgCl + Ca(NO_3)_2$ represents the former equation properly balanced.

18. $AlCl_3 + NaOH = Al(OH)_3 + NaCl.$
19. $Pb(NO_3)_2 + H_2SO_4 = PbSO_4 + HNO_3$
20. $AlCl_3 + Ca(OH)_2 = CaCl_2 + Al(OH)_3$

Complete and balance each of the following double decomposition equations. The metals or metal radicals exchange places with the acid radicals as shown in the sample.

Sample

$AgNO_3 + BaCl_2 =$ ..... + ...
When completed and balanced the above equation reads:
$2AgNO_3 + BaCl_2 = 2AgCl + Ba(NO_3)_2$

21. $FeSO_4 + NH_4OH =$ ..... + ...
22. $Al_2(SO_4)_3 + Ba(NO_3)_2 =$ ..... + ...

TURN IMMEDIATELY TO PAGE 4

Last Name .....

23. From the following equation, calculate how many grams of Na_2SO_3 will be required to produce 192 grams of SO_2.

$Na_2SO_3 + H_2SO_4 = Na_2SO_4 + SO_2 + H_2O$.

(Atomic weights: Na 23; S 32; O 16; H 1.)

Put answer here .....

24. The weight of one liter of SO_2 is .....grams.

(The necessary atomic weights are given in problem 23)

Balance the following equations using correct molecular formulas in each reaction:

25. $H + O = H_2O$.

26. $Na + H_2O = NaOH + H$

Complete and balance each of the following equations, using correct molecular formulas in each reaction.

27. $Zn + HCl =$ .....

28. $(NH_4)_2 SO_4 + NaOH =$ .....

29. From the following equation, calculate the number of liters of oxygen which will be required to completely burn 20 liters of CO: $2CO + O_2 = 2CO_2$.

Put answer here.....

30. If there are 40 liters of gas at 127 degrees centigrade, how many liters are there at 27 degrees centigrade, the pressure remaining constant?

Put answer here .....

Indicate the charges for each of the ions in the two following questions:

31. The ions for $NaNO_3$ are .....and.....

32. The ions for $Ca(OH)_2$ are ..... and .....

33. Write the following reaction as a complete ionic equation properly balanced:

Silver nitrate + hydrochloric acid. .....

TURN IMMEDIATELY TO PAGE 5

Last Name .....

In the following questions, only one answer to each question is correct. Underline the correct answer.

Sample

An alloy is: 1. an element; 2. a compound; 3. a radical; 4. a mixture; 5. an ion.

34. The fact that water always contains 11.18% of hydrogen by weight illustrates the law of: 1. Gay Lussac; 2. definite proportions; 3. multiple proportions; 4. Henry; 5. Berthollet.

35. According to the theory of ionization, a base is a compound which when dissolved in water produces:

1. hydrogen ions; 2. NO_3 ions; 3. OH ions; 4. hydrogen molecules; 5. OH molecules.

36. The pressure remaining constant, the volumes of gases vary: 1. directly as the temperature; 2. inversely as the temperature; 3. directly as the absolute temperature; 4. inversely as the absolute temperature; 5. directly as the centigrade temperature.

37. The fact that 20 grams of mercury will unite with 1.6 grams of oxygen to form 21.6 grams of mercuric oxide illustrates the law of: 1. multiple proportions; 2. conservation of matter; 3. Henry; 4. Charles; 5. Avogadro.

38. Determine the simple formula of a compound composed of carbon 85.71% and hydrogen 14.28% (At. Wts.: C 12; H 1.)

.....

TURN IMMEDIATELY TO PAGE 6

Last Name .....

Write the entire equations for the following reactions using correct molecular formulas in each case.

39. The preparation of hydrogen chloride from sulphuric acid and one other compound. .....

40. The action of hydrochloric acid on limestone or marble.

.....

(TURN BACK AND TRY AGAIN THE QUESTIONS YOU HAVE OMITTED)

CHEMISTRY TEST, FORM B.

Part I.

Last Name .....

Directions: In the following exercises, the formulas of 5 gases are listed at the top of each column and the properties of the gases are listed on the left. Place a cross (x) in each space where the property is the true answer and a cipher (0) where the property is a false answer. Leave a blank where you do not know the answer. In the case of each gas, start at the top and work down the column, as shown in the case of the first column marked A, which is already marked for you. The weight of one liter of air is 1.293 grams. The necessary atomic weights are given here.

A 40; H 1; N 14; C 12; O 16; He 4.

	A	H_2	N_2	CO_2	He
1. Colorless	X				
2. Odorless	X				
3. Heavier than air	X				
4. Same weight as air	O				
5. Lighter than air	O				
6. Supports Combustion	O				
7. Burns in air	O				
8. A lighted stick thrust into it goes out	X				
9. The gas is so soluble in water that it cannot be collected over water	O				
10. The gas is frequently generated in certain fire extinguishers	O				

Score .....

WHEN THROUGH TURN TO PAGE TWO

Part II

Last Name .....

In the exercises below, the valence to be used is as indicated in the following elements and radicals:
K^+; Al^{+++}; Cr^{++++++}; CO_3^{--}; PO_4^{---}; O^{--}.

Insert subscripts where necessary to make the following formulas correct:

Sample

$NaPO_4$. The figure 3 when placed under the Na gives the correct formula Na_3PO_4.

1. $K(CO_3)$; 2. $Al(CO_3)$; 3. $Al(PO_4)$; 4. CrO; 5. If in the list of generalized chemical formulas given below, B has a valence of 4, what is the valence of D?

A_2B; A_3C_2; DC_2 .....

Write the chemical name of the compound after each of the following formulas:

Sample

$HBrO_3$	Bromic Acid

6 HBr ..... 7. MgO .....

8. $KClO_4$ ..... 9. $NaNO_2$ .....

10. $NaHCO_3$ ..... 11. NaBrO .....

TURN IMMEDIATELY TO PAGE THREE

Last Name .....

Write the formulas after each of the following names:

Sample

Bromic Acid $HBrO_3$

12. Potassium iodide .....
13. Sodium bromate .....
14. Potassium sulphite .....
15. Ferrous hydroxide .....
16. Hypobromous acid .....
17. Potassium dichromate .....

Balance the following equations:

Sample

$AgNO_3 + CaCl_2 = \underline{AgCl} + Ca(NO_3)_2$

When the correct numbers are placed before the proper formulas the equation is balanced correctly.

Thus, $2AgNO_3 + CaCl_2 = \underline{2AgCl} + Ca(NO_3)_2$ represents the former equation properly balanced.

18. $AlCl_3 + KOH = \underline{Al(OH)_3} + KCl$
19. $BaCl_2 + (NH_4)_2CO_3 = \underline{BaCO_3} + NH_4Cl$
20. $Fe(NO_3)_3 + Ca(OH)_2 = Ca(NO_3)_2 + \underline{Fe(OH)_3}$

Complete and balance each of the double decomposition equations. The metals or metal radicals exchange places with the acid radicals as shown in the sample.

Sample

$AgNO_3 + BaCl_2 =$ ..... + ...

When completed and balanced the above equation reads:

$2AgNO_3 + BaCl_2 = 2AgCl + Ba(NO_3)_2$

21. $CaCl_2 + H_2SO_4 =$ ..... + ...
22. $Ba(NO_3)_2 + Fe_2(SO_4)_3 =$ ..... + ...

TURN IMMEDIATELY TO PAGE FOUR

Last Name .....

23. From the following equation, calculate how many grams of HCl will be required to produce 136 grams of H_2S.

$2HCl + FeS = H_2S + FeCl_2$

(At. Wts.: H 1; Cl 35.5; Fe 56; S 32.)

Put answer here .....

24. The weight of one liter of H_2S is .....grams.
(At. Wts.: H 1; S 32.)

Balance the following equations, using correct molecular formulas in each reaction.

25. $N + O = NO$

26. $Ca + H_2O = Ca(OH)_2 + H$.

Complete and balance the following equations, using the correct molecular formulas in each reaction.

27. $Zn + H_2SO_4 =$ .....

28. $NH_4Cl + Ca(OH)_2 =$ .....

29. From the following equation, calculate the number of liters of oxygen which will be required to completely burn 10 liters of C_2H_2:

$2C_2H_2 + 5O_2 = 4CO_2 + 2H_2O$.

Put answer here .....

30. If there are 60 liters of gas at 570 mm of pressure, how many liters are there at 600 mm. of pressure, the temperature remaining constant?

Put answer here .....

Indicate the charges for each of the ions in the following questions:

31. The ions for HCl are ..... and .....

32. The ions for Na_2SO_4 are ..... and .....

Write the following reaction as a complete ionic equation properly balanced:

33. Sodium chloride + silver nitrate

.....

TURN IMMEDIATELY TO PAGE 5

Last Name .....

In the following questions, only one answer to each question is correct: Underine the ccorect answer.

Sample

An alloy is: 1. an element; 2. a compound; 3. a radical; 4. a mixture; 5. an ion.

34. According to the theory of ionization, an acid is a compound which when dissolved in water produces:
1. OH ions; 2. H atoms; 3. Cl ions; 4. NO_3 ions; 5. H ions.
35. The fact that nitrogen and oxygen unite to form several oxides illustrates the law of: 1. Charles; 2. multiple proportions; 3. definite proportions; 4. Gay Lussac; 5. Boyle.
36. The temperature remaining constant, volumes of gases vary:
1. directly as the density; 2. inversely as the pressure; 3. directly as the pressure; 4. inversely as the density; 5. directly as the absolute temperature.
37. The fact that 2 liters of nitric oxide will unite with one liter of oxygen to produce 2 liters of nitrogen dioxide illustrates the law of: 1. definite proportions; 2. Gay Lussac; 3. multiple proportions; 4. ionization; 5. periods.
38. Determine the simple formula of a compound composed of carbon 75% and hydrogen 25%. (At. Wts.; C 12; H 1.)

Put answer here .....

TURN IMMEDIATELY TO PAGE SIX

Last Name .....

Write the entire equations for the following reactions, using correct molecular formulas in each case:
39. The preparation of nitric acid from sulphuric acid and one other compound: .....
40. Lime water and ammonium chloride heated: .....

.....

(TURN BACK AND TRY AGAIN THE QUESTIONS YOU HAVE OMITTED)

CHEMISTRY TEST, FORM X

Last Name .....

In the exercises below, the valence to be used is as indicated in the following elements and radicals:
K^+; Ca^{++}; Al^{+++}; Mn^{++++}; Cr^{++++++}; NO_3^-; O^{--}; PO_4^{---}

Write the correct formula of the compound after each of the following formulas. If the formula is already correct, copy it in the blank.

Sample

KPO_4	K_3PO_4

1. KO ..... 2. $AlNO_3$ .....
3. $CaPO_4$ ..... 4. $AlPO_4$ .....
5. MnO ..... 6. CrO .....

Write the chemical name of the compound after each of the following formulas:

Sample

$HClO_3$	Chloric Acid

7. $NaClO_4$ ..... 8. $KClO_2$ .....
9. MgO ..... 10. K_2SO_3 .....

Last Name .....

Write in the formulas after each of the following names:

Sample

Chloric acid $HClO_3$

11. Chlorous acid ..... 12. Sodium hypochlorite .....
13. Mercuric oxide ..... 14. Manganese sulphide .....

Balance the following equations using correct molecular formulas in each reaction:

15. $H + O = H_2O$
16. $Na + H_2O = NaOH + H$
17. $N + O = NO$

Write the ions and mark them with their charge or charges for each of the following compounds:

18. HCl ..... and .....

19. Na_2SO_4 ..... and .....

20. $Ca(NO_3)_2$ ..... and .....

Write the following reactions as complete ionic equations properly balanced:

21. Sodium chloride + silver nitrate .....

22. Calcium hydroxide + hydrochloric acid .....

Last Name .....

In the following questions, only one answer to each question is correct. Underscore the correct answer.

Sample

An allow is: 1. an element; 2. a compound; 3. a radical; 4. a mixture; 5. an ion.

23. The fact that iron and oxygen unite to form several oxides illustrates the law of: 1. Charles; 2. multiple proportions; 3. definite proportions; 4. Gay Lussac; 5. Boyle.

24. The fact that two liters of nitric oxide will unite with one liter of oxygen to produce 2 liters of nitrogen dioxide illustrates the law of: 1. definite proportions; 2. Gay Lussac; 3. multiple proportions; 4. ionization; 5. periods.

Write the entire equation properly balanced for the following reaction, using correct molecular formulas in each case:

25. Lime water and ammonium sulphate heated.

.....

CHEMISTRY TEST, FORM Y

Date of test .....

Grade .....

Name .....

School .....

Total number of months you have studied chemistry .....

Score .....

Directions

Below and on the following page are two types of questions on chemistry. The directions and one sample question are given. Be sure to follow directions. Try to do as many of the questions as you can. Use the margins and backs of these sheets for all figuring. Ask no questions during the test. You will be allowed sufficient time to complete the test.

In the following questions, only one answer to each question is correct. Underscore the correct answer.

Sample

An alloy is: 1. an element; 2. a compound; 3. a radical; 4. a mixture; 5. an ion.

1. The fact that 2 liters of nitric oxide will unite with one liter of oxygen to produce 2 literes of nitrogen dioxide illustrates the law of: 1. definite proportions; 2. Gay Lussac; 3. multiple proportions; 4. ionization; 5. periods.

2. According to the modern theory of valence, the hydrogen atom becomes H+ when the atom: 1. takes on one proton; 2. loses a positive charge of electricity; 3. takes on one electron; 4. loses one external electron; 5. takes on one negative charge of electricity.

Write the answer to each problem in the blank space.

3. If a liter of gas weighs 1.25 grams, its molecular weight is .....grams.

4. If a liter of gas weighs 1.16 grams, its molecular weight is .....grams.

5. The per cent of water of crystallization in $CuSO_4.5H_2O$ is..... (At. Wts.: Cu, 64; S, 32; H, 1; O, 16)

6. The per cent of sodium in $Na_2CO_3.10H_2O$ is ..... (At. Wts.: Na, 23; C, 12; O, 16; H, 1.)

Questionnaire

If the physical and chemical properties of the following gases are taught during the regular classroom procedure, place a check mark after each gas in the column marked "class." If demonstration, group, or individual experiments are performed, place a check mark after each gas in the column marked "Experiments." If both procedures are followed be sure to have checks in both columns.

	Class	Experiments
1. Oxygen		
2. Chlorine		
3. Carbonmonoxide		
4. Argon		
5. Hydrogen		
6. Nitrogen		
7. Carbondioxide		
8. Helium		

For the following items, place a check mark in the "Yes" column after each item that is taught and a check mark in the "No" column after each one that is not taught.

	Yes	No
1. Valence		
2. Naming chemical formulas		
3. Writing chemical formulas		
4. Balancing chemical equations		
5. Writing double decomposition equations		
6. Writing molecular equations (Example: $2Na + 2H_2O = 2NaOH + H_2$)		
7. Writing completion equations (Example: $Zn + H_2SO_4 = ?$)		
8. Writing entire equations (Example: The action of hydrochloric acid upon limestone)		
9. Writing oxidation equations (Example: $Cu + HNO_3 = ?$)		

	Yes	No
10. Writing reduction equations		
11. Writing the ions for given compounds (Example: $NaCl = Na^+ \ Cl^-$)		
12. Writing ionic equations (Example: $Ag^+ + NO_3^- + H^+ + Cl^- = AgCl + H^+ + NO_3^-$) Problems involving the following principles:		
13. Finding the weight of a liter of gas with atomic weights given.		
14. Computing the weight of a product or reagent in a chemical reaction when the weight of one of the reagents or products and the atomic weights are given.		
15. Computing the volume of a reagent or product in a chemical reaction when one of the volumes is given. (Example: How many liters of oxygen are required to completely burn 10 liters of C_2H_2?)		
16. Charles law		
17. Boyle's law		
18. Both Charles's law and Boyle's law		
19. Computing the formula with the percentage composition and atomic weights given.		
Laws and Definitions:		
20. Law of definite proportions		
21. Law of conservation of matter.		
22. Law of multiple proportions		
23. Charles's law		
24. Boyle's law		
25. Gay Lussac's Law (combining volumes)		
26. Definition for a base (ionic standpoint)		
27. Definition for an acid (ionic standpoint)		

Kindly list on the back of this sheet the principal chemistry texts and manuals used, stating the author, title, publishing company, and the date of the edition in each case.

If course of study in chemistry is available, will you kindly mail me a copy?

Signature .....

Official Position .....

City and State .....

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